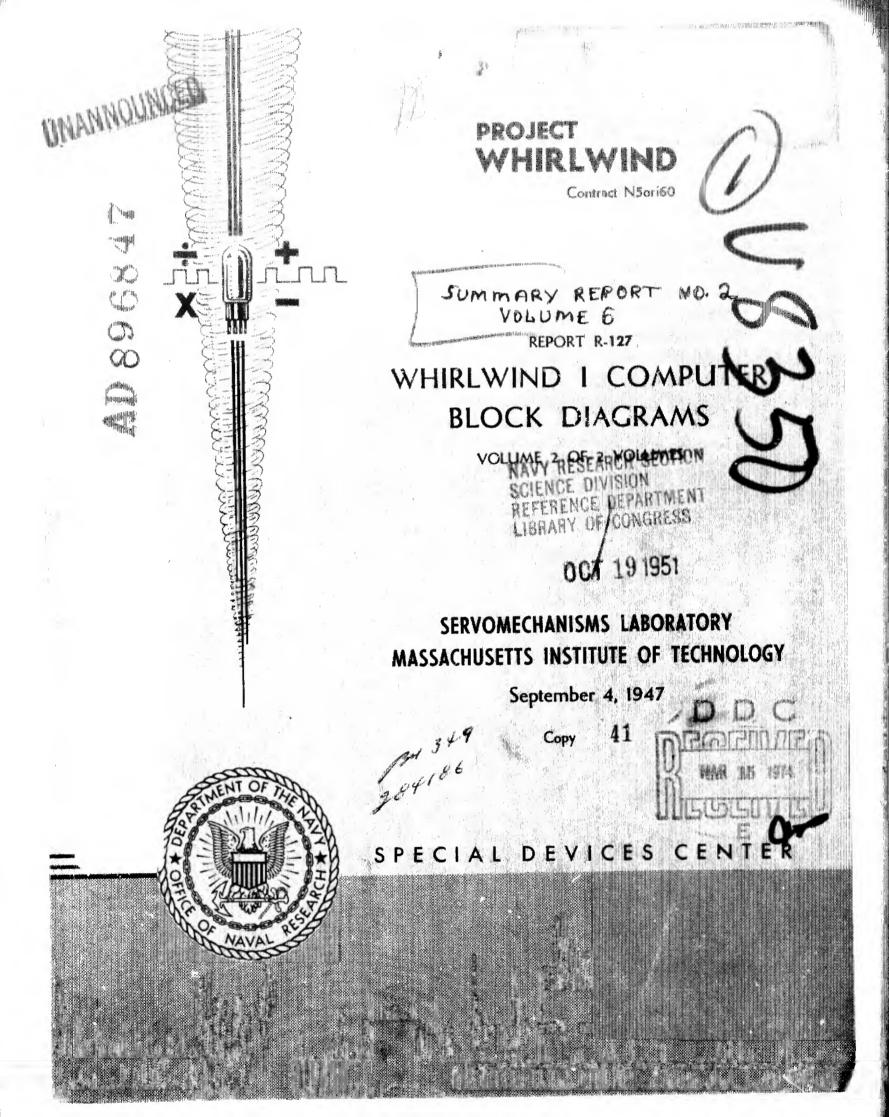
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PROJECT (DEVICE 24-X-3)



WHIRLWIND I COMPUTER BLOCK DIAGRAMS,

VOLUME 2, OF 2 VOLUMES

Submitted to the

SPECIAL DEVICES CENTER

OFFICE OF NAVAL RESEARCH

Under Contract N5ori60



Report by

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SERVOMECHANISMS LABORATORY MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Cambridge 39, Massachusetts

Project DIC-6345

September 4, 1947

FOREWORD

This report is a description of the Whirlwind electronic digital computers under development at the Servomechanisms Laboratory of M. I. T. for the Office of Naval Research. The arithmetic nature and the physical nature of the computers are covered briefly, and the block diagrams for the prototype computer WWI are discussed in some detail.

The report consists of two volumes: Volume 1 contains the text and Volume 2 the drawings.

LIST OF DRAWINGS

Figure Number	Drawing Number	Title
1	A-30339	General Block Diagram
2	A-30445	Store Result
3	A-30440	Origin of Orders
4	A-30441	Setup Order
5	A-30442	Read Out Order
6	A-30443	Setup Operation
7	A-30444	Perform Operation
8	A-30446	Subprogram
9	A-30454	Electronic Switch
10	A-30452	Time Pulse Distributor
11	A-30453	Control
12	A-30400	Decimal Addition
13	A-30401	Binary Addition
14	A-30402	A Binary Adder
15	A-30417	Negative Numbers
16	A-30410	Subtraction Using 9's Complement
17	A-30403	Decimal Multiplication
18	A-30355	Binary Notation
19	A-30409	Binary Multiplication
20	A-30404	Modified Binary Multiplication
21	A-30447	Multiplication I
22	A-30448	Multiplication II
23	A-30449	Multiplication III
24	A-30450	Multiplication IV
25	A-30451	Multiplication V
26	A-30406	Rounding Off
27	A-30683	Decimal Division
28	A-30686	Binary Division
29	C-37072	Arithmetic Element
30	A-30433	Accumulator
31	A-30432	Accumulator
32	A-30685	Shift and Carry
33	A-30684	Shift Left
34	C-37099	Clear and Add
35	C-37100	Add
36	A -30682	Arithmetic Check
37	C-37101	Clear and Subtract
38	C-37102	Subtract
39	C-37103	Multiply and Roundoff
40	C-37104	Divide
41	C-37105	Transfer to Storage
42	C-37106	Shirt Right
43	C-37107	Shift Left
44	C-37108	Conditional Program
45	C-37109	Special Add
46	C-37071	System Block Diagram
47	B-37073	Control Functions
48	B-37070	Bus Connections

LIST OF DRAWINGS

Figure Number	Drawing Number	Title
49	B-37098	Control
50	B-37058	Master Clock
51	B-37062	Program Counter
52	B-37067	Program Register
53	B-37066	Control Switch
	C-37077	Operation Matrix I
54	C-37078	Operation Matrix II
55	B-37076	Time Pulse Distributor Control
56	B-37068	Pulse Distributor
57	B-37075	Program Timing Matrix
58	C-37064	Storage Chassis Arrangement
59	B-37057	Flip-flop Storage Section
60	B-37060	Storage Output Section
61	B-37060	Flip-flop Storage Control
62	C-37072	Arithmetic Element
63	B-37056	Section of A-Register
64		Accumulator Sections
65	C-37063	Accumulator Sections
66	C-37096	B-Register Sections
67	B-37069	B-Register Sections
68	B-37097	Step Counter
69	B-37074	Check Register
70	B-37065	Program Timing
71	A-30874	Timing for Add
72	B-37080	Timing for Add Timing for Clear and Add
73	B-37081	Timing for Clear and Add Timing for Subtract
74	B-37082	Timing for Subtract Timing for Clear and Subtract
75	B-37083	Timing for Multiply and Roundoff
76	B-37084	Timing for Multiply and Hold Full Product
77	B-37085	
78	B-37094	Timing for Divide
79	B-37086	Timing for Transfer to Storage
80	B-37088	Timing for Shift Right
81	B-37089	Timing for Shift Left
82	B-37090	Timing for Subprogram
83	B-37091	Timing for Conditional Program
84	B-37092	Timing for Transfer Digits
85	B-37093	Timing for Special Add
86	B-37087	Timing for Store & Display
87	B-37001	Parallel Digit Computer Codes

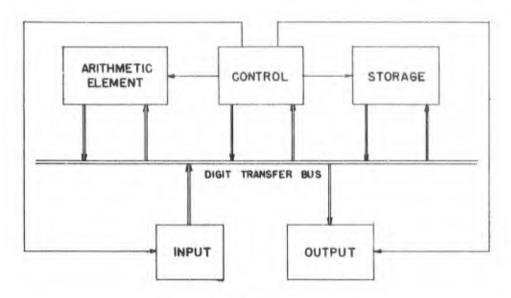


Figure 1
GENERAL BLOCK DIAGRAM

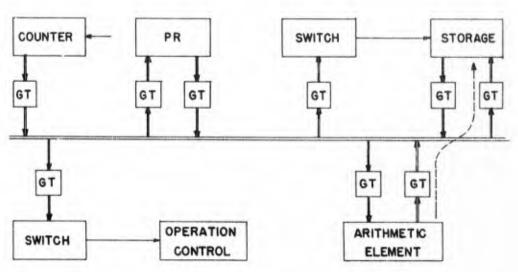


Figure 2
STORE RESULT

ORIGIN OF ORDERS



Figure 3
ORIGIN OF ORDERS

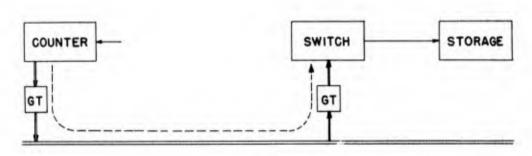


Figure 4
SETUP ORDER

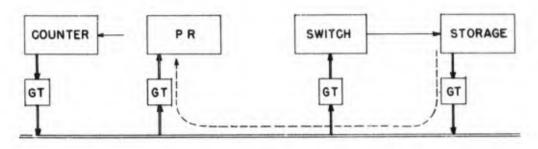


Figure 5

READ OUT ORDER

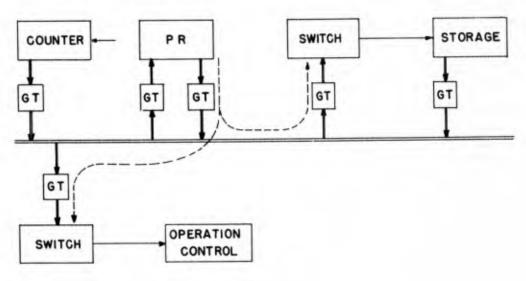


Figure 6
SETUP OPERATION

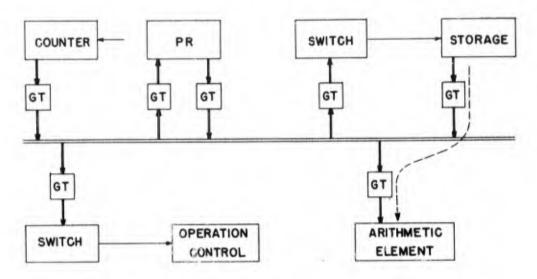


Figure 7
PERFORM OPERATION

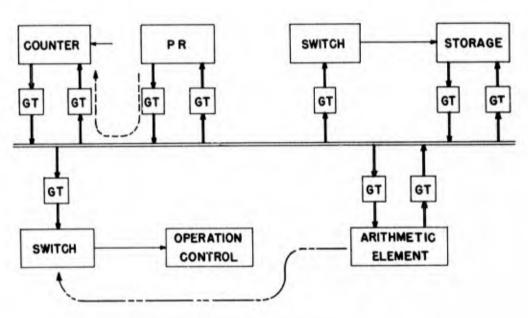


Figure 8
SUBPROGRAM

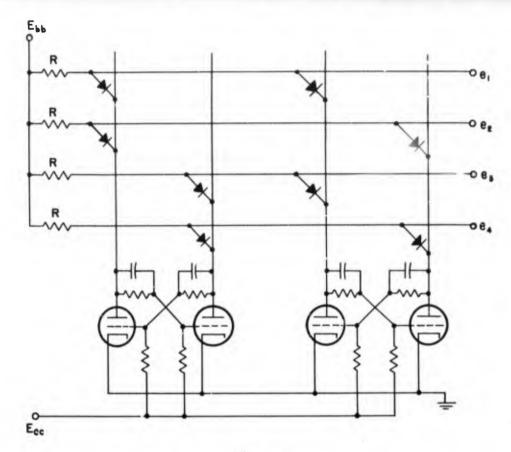


Figure 9
ELECTRONIC SWITCH

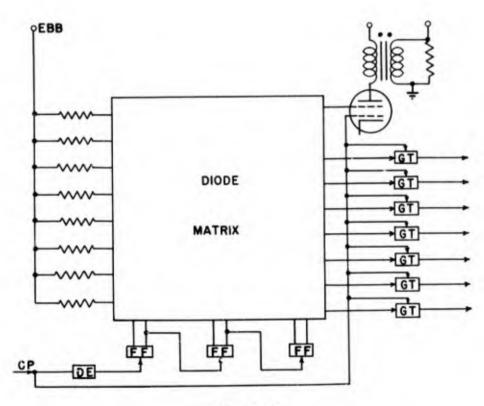


Figure 10
TIME PULSE DISTRIBUTOR

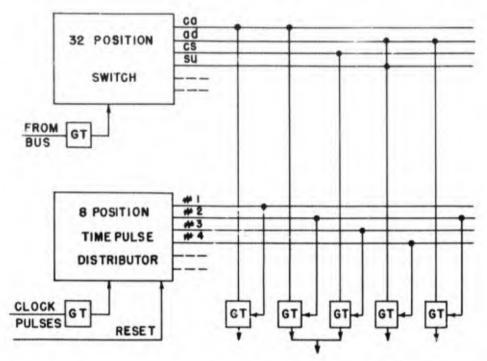


Figure 11 CONTROL

Figure 12
DECIMAL ADDITION

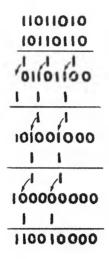


Figure 13
BINARY ADDITION

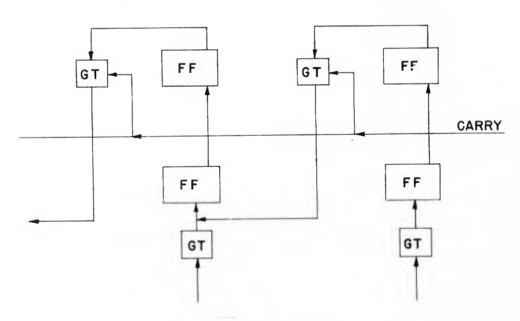


Figure 14 A BINARY ADDER

	DECIMAL	BINARY
POSITIVE NUMBER	223	11011111
NEGATIVE "	- 223	- 1101111
10'S COMPLEMENT	1 777	10000001
9's "	1776	100100000

Figure 15
NEGATIVE NUMBERS

Figure 16
SUBTRACTION USING 9'S COMPLEMENTS

Figure 17
DECIMAL MULTIPLICATION

REPRESENTS POWERS OF 2

MULTIPLICATION TABLE:

1 X 1 = 1 1 X 0 = 0 0 X 0 = 0

ADDITION:

1 + 1 = 10 1 + 0 = 1 0 + 0 = 0

BINARY COLUMNS ≈ 3 1/3 X DECIMAL COLUMNS

ONLY DIGITS I AND O REQUIRED IN EQUIPMENT

Figure 18
BINARY NOTATION

10110	MULTIPLICAND	22
10011	MULTIPLIER	19
10110		198
10110		22
1000010	PARTIAL PRODUCT	418
00000		
1000010	PARTIAL PRODUCT	r
00000		
01000010	PARTIAL PRODUC	T
10110		
110100010	= 418 PRODUC	Γ

Figure- 19
BINARY MULTIPLICATION

STEPI	10110 MULTIPLICAND 10011 MULTIPLIER 10110 PARTIAL PRODUCT
STEP 2	10110 MULTIPLICAND 1001 SHIFTED MULTIPLIER 10110 SHIFTED PARTIAL PRODUCT 10100 PARTIAL PRODUCT
STEP 3	10110 MULTIPLICAND 100 SHIFTED MULTIPLIER 1000010 SHIFTED PARTIAL PRODUCT 00000 1000010 PARTIAL PRODUCT
STEP 4	10110 MULTIPLICAND 10 SHIFTED MULTIPLIER 1000010 SHIFTED PARTIAL PRODUCT 00000 01000010 PARTIAL PRODUCT
STEP 5	10110 MULTIPLICAND SHIFTED MULTIPLIER 01000010 SHIFTED PARTIAL PRODUCT 110100010 PRODUCT

Figure 20 MODIFIED BINARY MULTIPLICATION

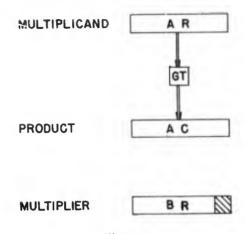


Figure 21
MULTIPLICATION I

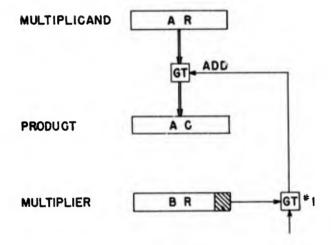


Figure 22
MULTIPLICATION II

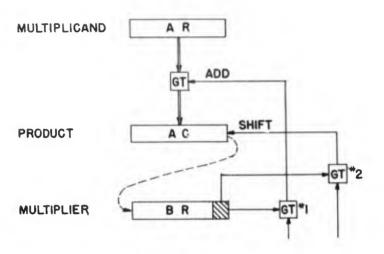


Figure 23
MULTIPLICATION III

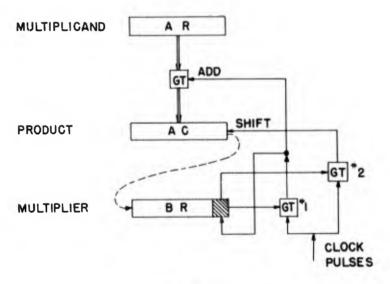


Figure 24
MULTIPLICATION IV

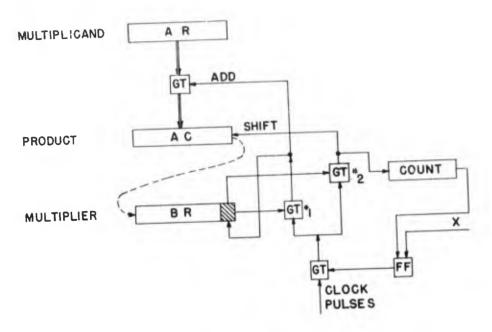


Figure 25
MULTIPLICATION V

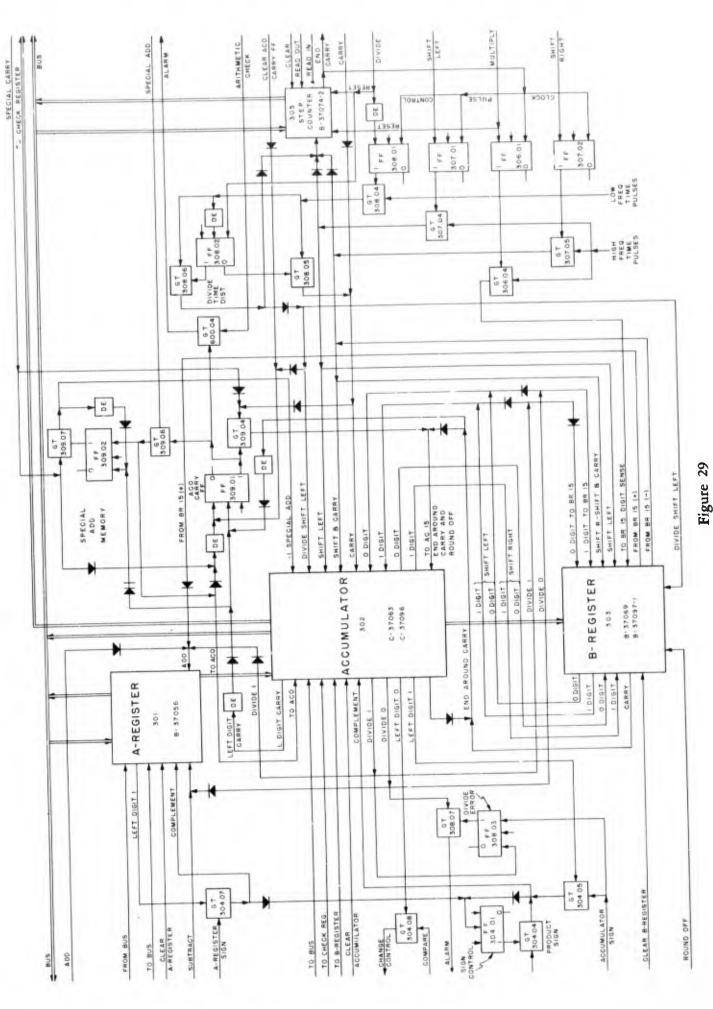
Figure 26 ROUNDING OFF

4 2	
28 3976	
-2 8	SUBTRACT I
1 1 7 6	POS. REMAINDER
-2 8	SUBTRACT &
-1 6 2 4	OVERCAST
+2 8	RESTORE - I
1176	SHIFT ! NET SUBTRACTION
- 2 8	SUBTRACT I
896	POS. REMAINUER
- 2 8	SUBTRACT 2
6 1 6	POS. REM.
-26	SUBTRACT 3
3 3 6	POS. REM.
- 2 8	SUBTRACT 4
5 6	POS. REM.
- 2 8	SUBTRACT 5
- 2 2 4	OVERCAST
+ 2 8	RESTORE -I
5 6	SHIFT 4 NET SUBTRACTION
- 2 8	SUBTRACT [
2 8	POS. REM.
2 8	SUBTRACT 2
0	POS. REM.
-28	SUBTRACT 3
- 2 8	OVERCAST
+ 2 8	RESTORE -I
0	REMAINDER O 2 NET SUB.

Figure 27
DECIMAL DIVISION

0.101 0.1 1 0 0.101 0.0 1 1 1 0 1.0 1 0 1 1 1.1 1 0 0 1 1.1 0 0 1 1 0.1 0 1 0 0	SUBTRACT NEG. REMAINDER O IN QUOTIENT SHIFT LEFT ADD
(1 0.0 0 1 1 1	END AROUND CARRY POS. REMAINDER 1 IN QUOTIENT
0.0 1 0 0 0 0.1 0 0 0 0 1.0 1 0 1 1	SHIFT LEFT SUBTRACT
1.1 1 0 1 1	NEG.REMAINDER O IN QUOTIENT Shift Left add
0.0 1 0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 1 0 0 0 1 0	END AROUND CARRY POS. REMAINDER I IN QUOTIENT SHIFT LEFT SUBTRACT
0.00100	END AROUND CARRY POS. REMAINDER I IN QUOTIENT SHIFT LEFT SUBTRACT
1.1 0 0 1 1	NEG. REMAINDER O IN QUOTIENT

Figure 28
BINARY DIVISION



ARITHMETIC ELEMENT

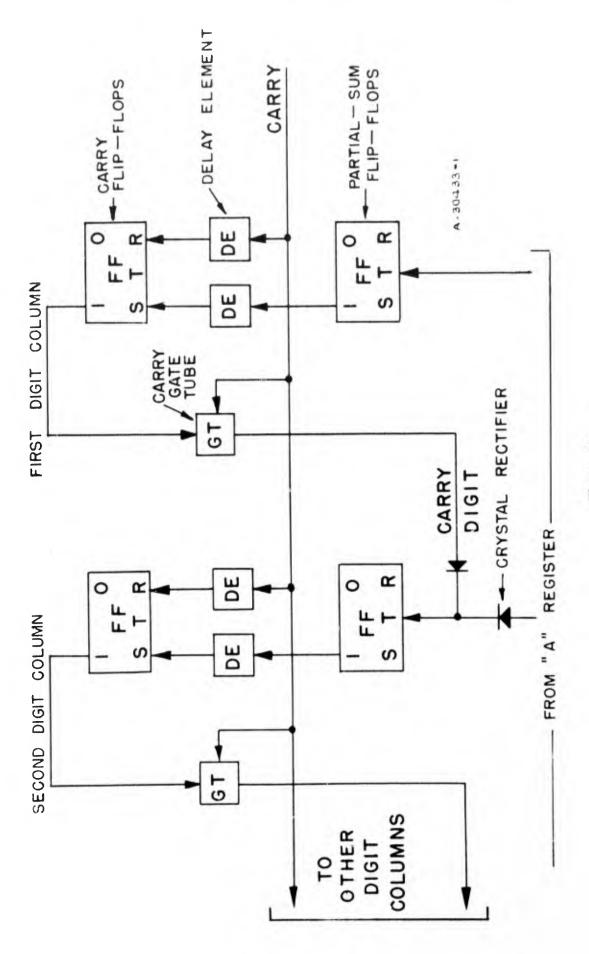


Figure 30 ACCUMULATOR

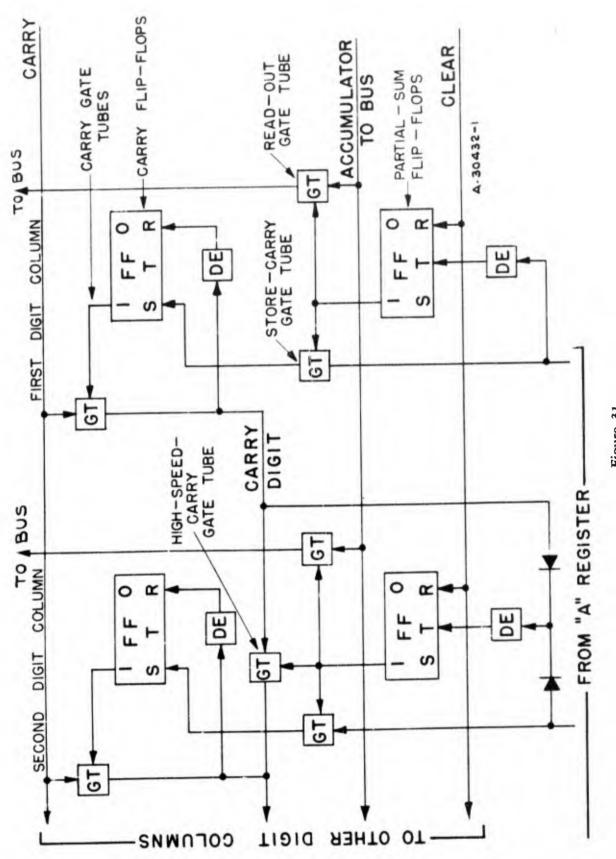


Figure 31 ACCUMULATOR

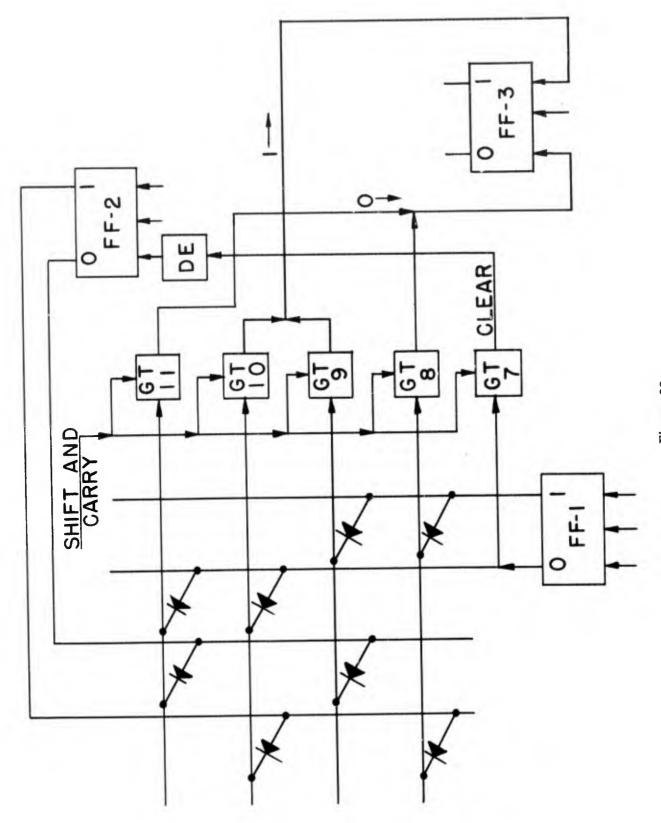


Figure 32 SHIFT AND CARRY

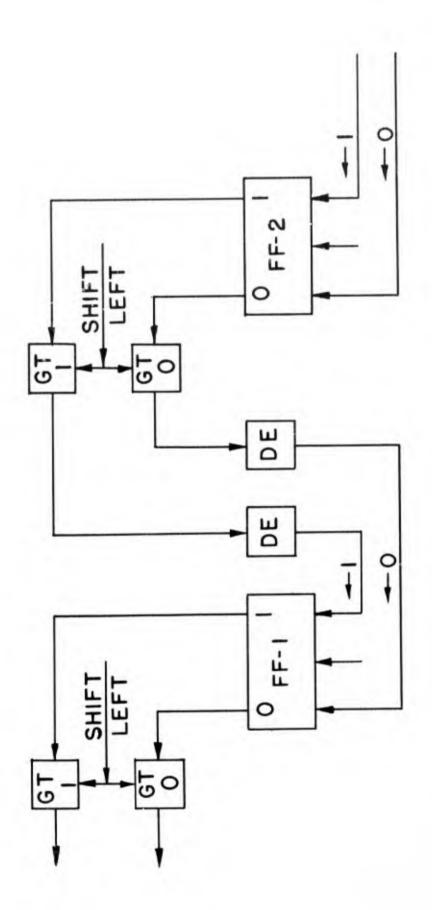


Figure 33 SHIFT LEFT

SOB

Figure 34 CLEAR AND ADD

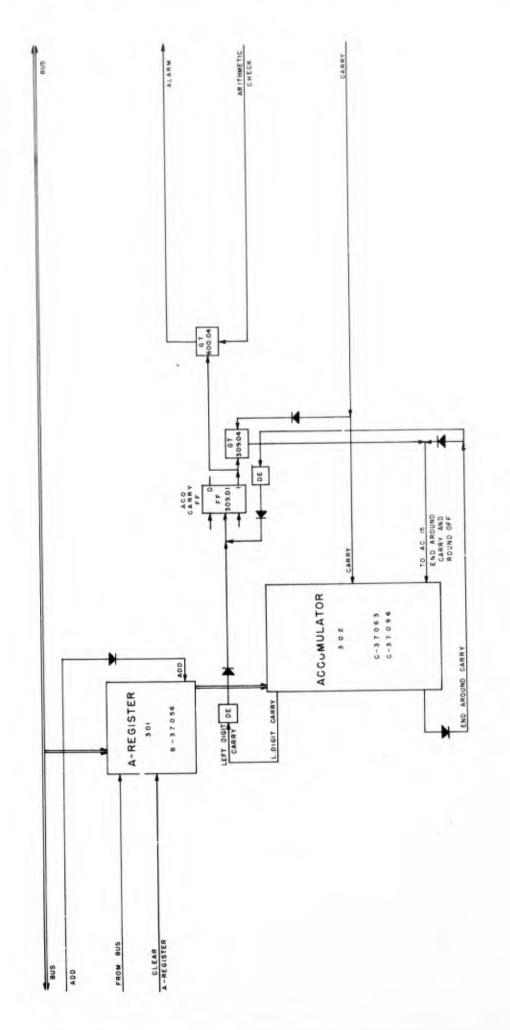


Figure 35 ADD

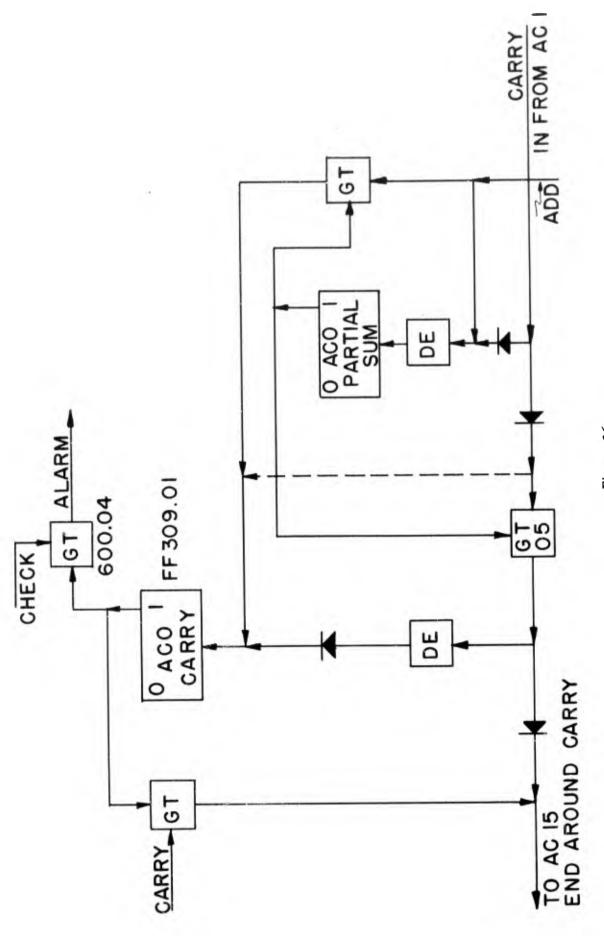


Figure 36
ARITHMETIC CHECK

Figure 37 CLEAR AND SUBTRACT

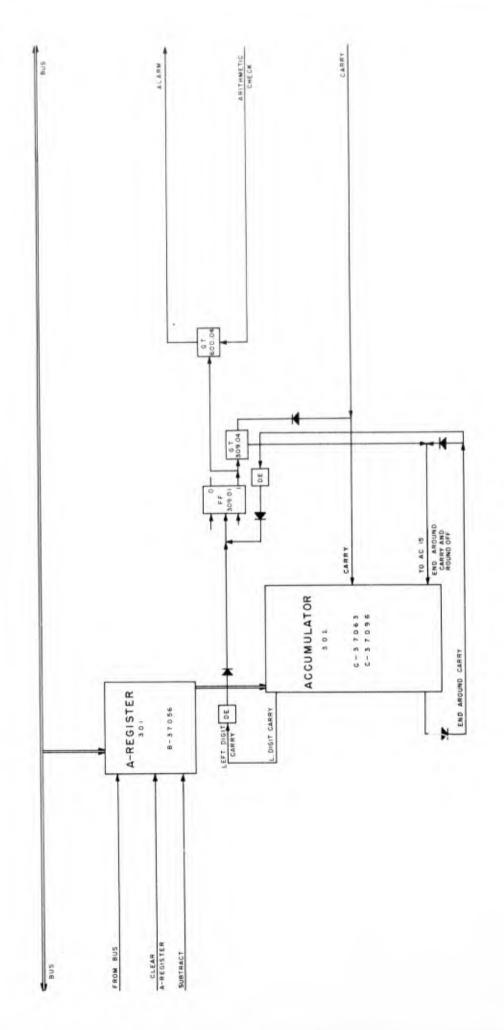


Figure 38 SUBTRACT

305 STEP COUNTER 8-37074-2 304.01 SHIFT R - SHIFT & CARRY TO BR IS DIGIT SENSE FROM BR (5 (+) FROM BR 15(+) END AROUND CARRY AND ROUND OFF 8-37097-1 ACCUMULATOR B-REGISTER 8-37069 0-37063 3 0 3 308 END AROUND CARRY 400 A-REGISTER CARRY COMPLEMENT 8-37056 LEFT DIGIT I COMPLEMENT LEFT DIGIT ! CLEAR B-REGISTER TO B-REGISTER A-REGISTER SIGN CLEAR CLEAR A-REGISTER FROM BUS ROUND DFF

MULTIPLY AND HOLD FULL PRODUCT

MULTIPLY AND ROUNDOFF

Figure 39

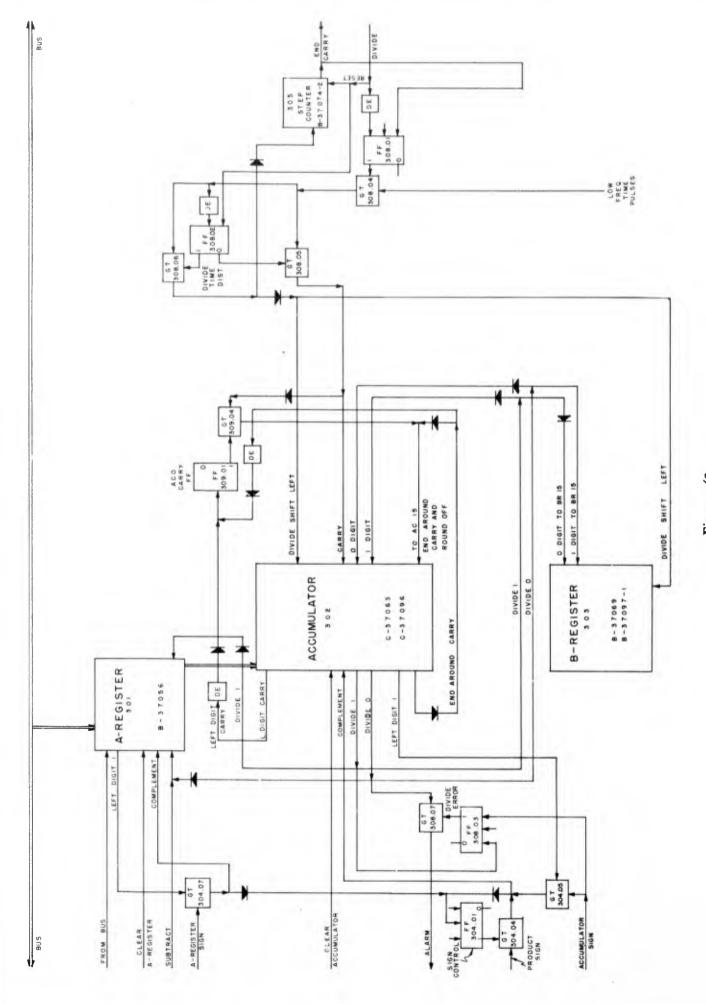
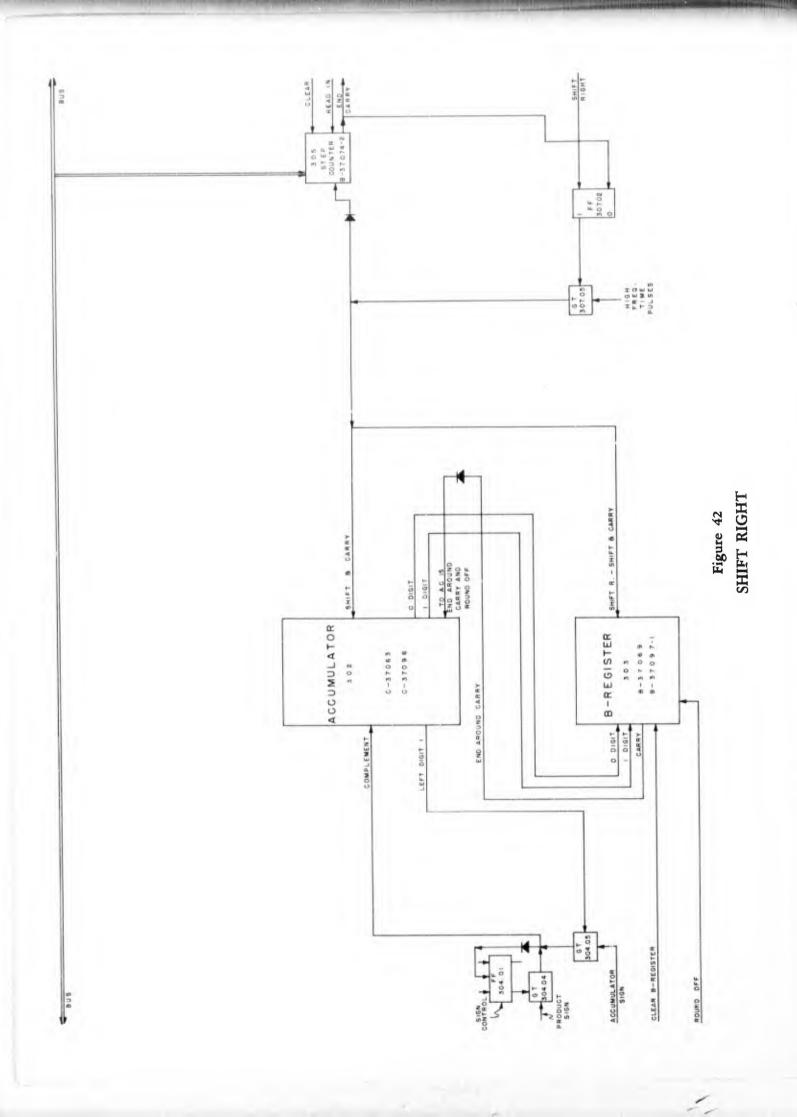


Figure 40 DIVIDE

Figure 41
TRANSFER TO STORAGE
TRANSFER DIGITS
STORE AND DISPLAY



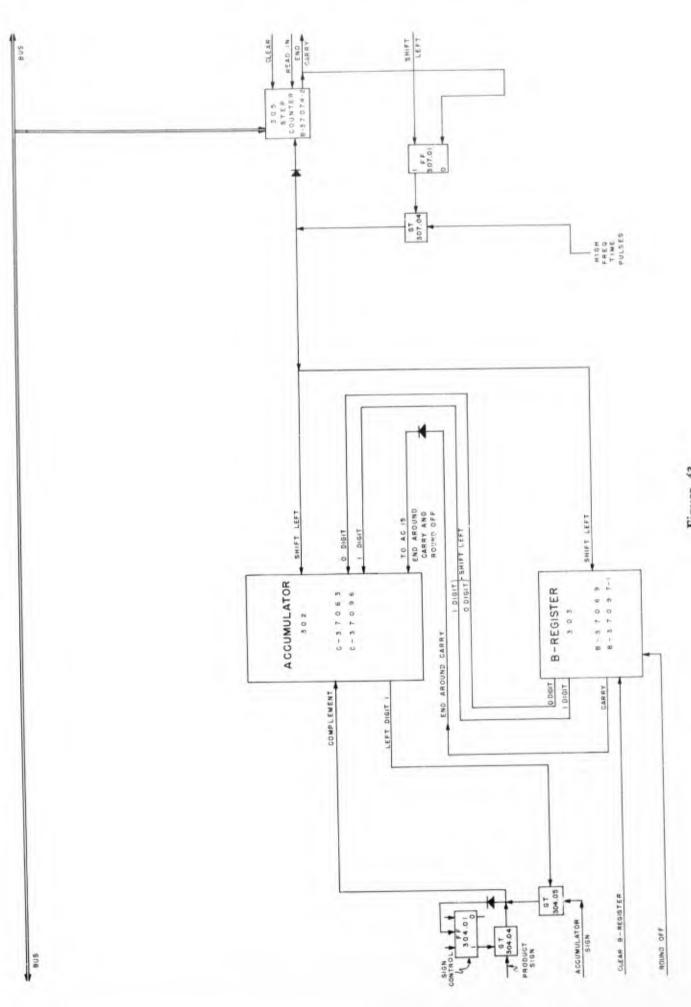


Figure 43 SHIFT LEFT

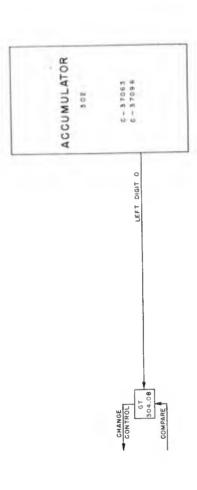


Figure 44
CONDITIONAL PROGRAM

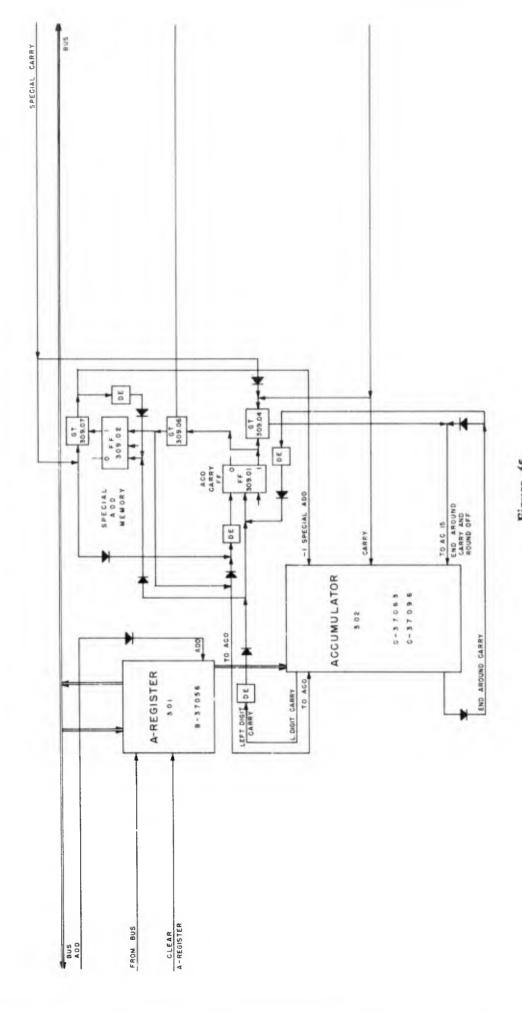
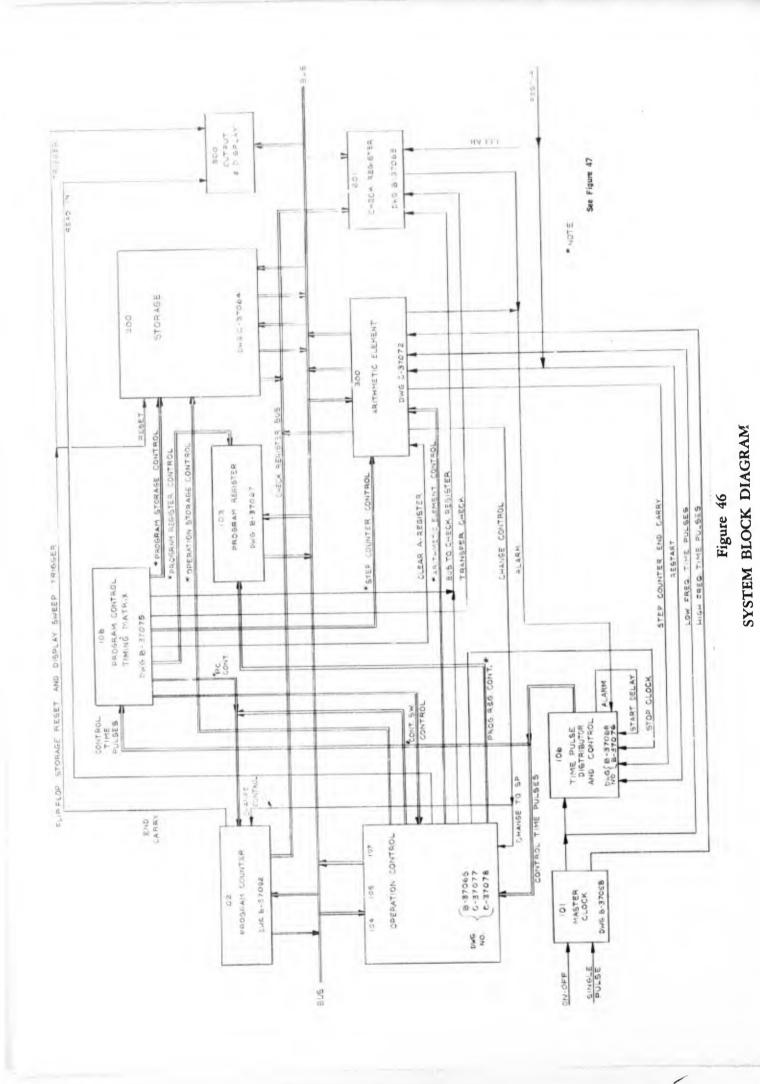


Figure 45 SPECIAL ADD



ARITHERIG ELEMENT CONTROL

PROGRAM COUNTER CONTROL

PROGRAM STORAGE CONTROL

4	Bus to A-Register	GT	301.01	ŗi	In from Bus	0T 102.C1	H	Bus to Storage Switch	GT 201.01
2,	A-Register to Bus	10	301.02	6,	Out to Bus	OT 102.02	໙ໍ		GT 201.02
*	Subtract: A-Register to Accum.	GT	301.04	W	Out to Check Register GT 102.03	GT 102.03	ķ		GT 203.02
#	Add: A-Register to Accumulator GI	-	301.05	#	Add Pulse		#		
ņ	Accumulator to Bus	10	302.02	ιŲ	Glear		ņ		GT 203.03
•	Accumulator to Check Register	OT	302.03						
*	Accumulator to B-Register	T-O	302.04		PROGRAM REGISTER CONTROL	CONTROL			
wo	Garry	GT	302.20	H	In from Bus	or 103.01		OPERATION STORAGE CONTROL	
6	Roundoff	5	303.08	8	Out to Bus	GT 103.02	r i		OT 203.01
10.	Product Sign	F	304.04	ъ.	Clear		αi	Storage Readout	GT 203.02
11.	Accumulator Sign	GT	304.05				3	Out to Check Register	dT 203.03
12.	A-Register Sign	5	304.07		CONTROL SWITCH CONTROL	ONTROL	a *	Storage Clear	
13.	Compare	G.	304.08	4	In from Bus	OT 104.01			
14.	Multiply	fine Since	306.01	ĸ.	Out to Bus	GT 104.02			
15.	Shift Left	Eng Size	307.01	w,	Clear				
16.	Shift Right	FF	307.02						
17.	Divide	Sec.	305.01	,	STEP COUNTER CONTROL	THOP			
15.	Special Add	GT 3	309.06	i (In Iron bus	or 305.01			
19.	Arithmetic Gheck	OT 6	500.04	ni i	Out to Bus	GT 305.02			
20.	Clear Accumulator			ň	Clear				
21.	Clear B-Register								
22.	Special Carry							NOTE: See Figura 46	

CONTROL FUNCTIONS Figure 47

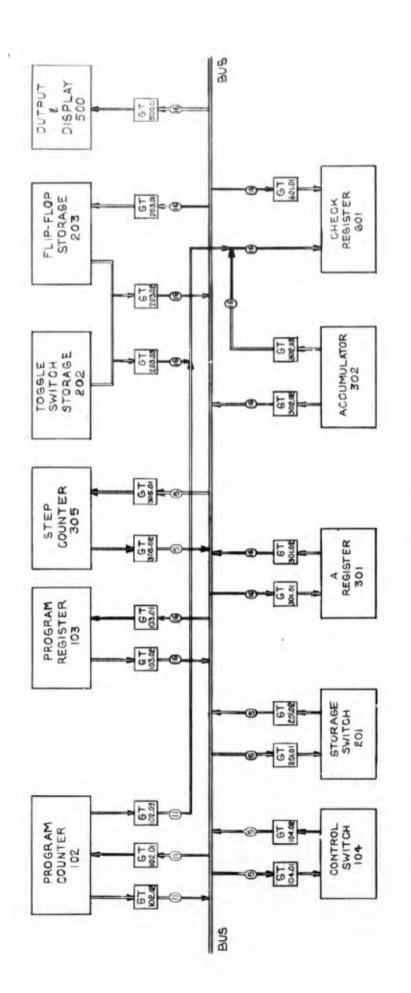
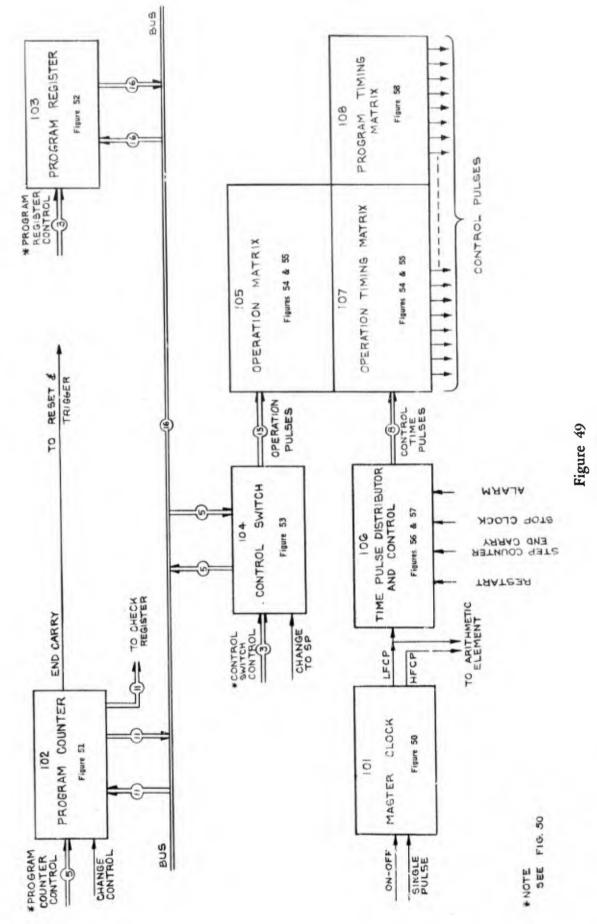


Figure 48
BUS CONNECTIONS



CONTROL

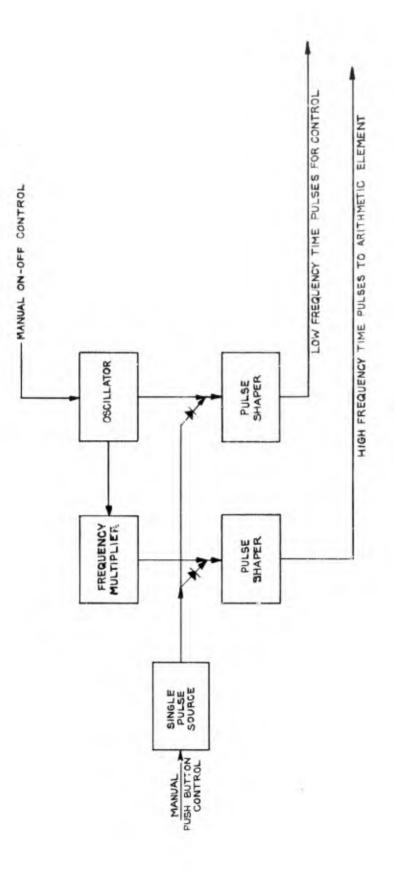


Figure 50
MASTER CLOCK

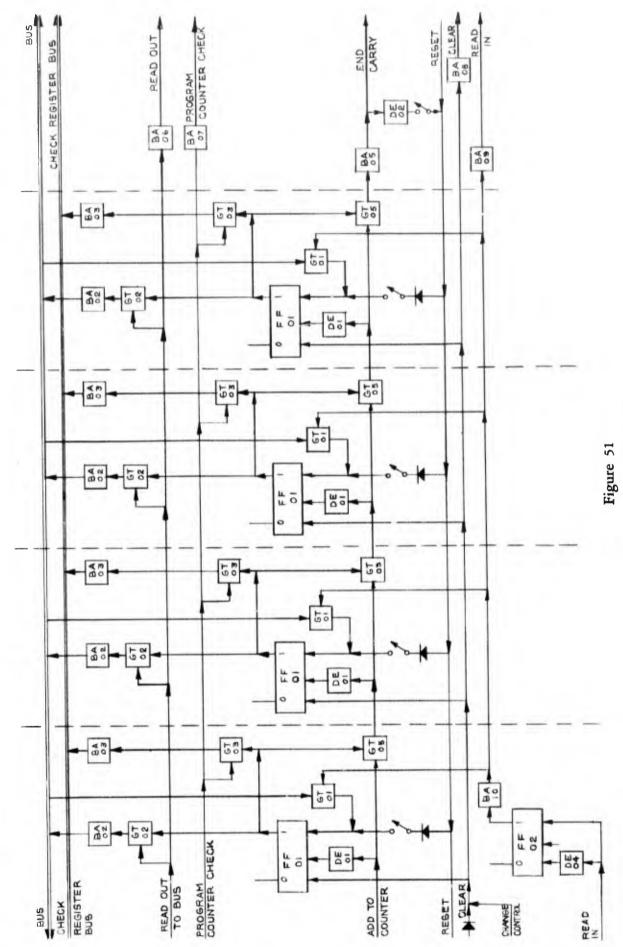
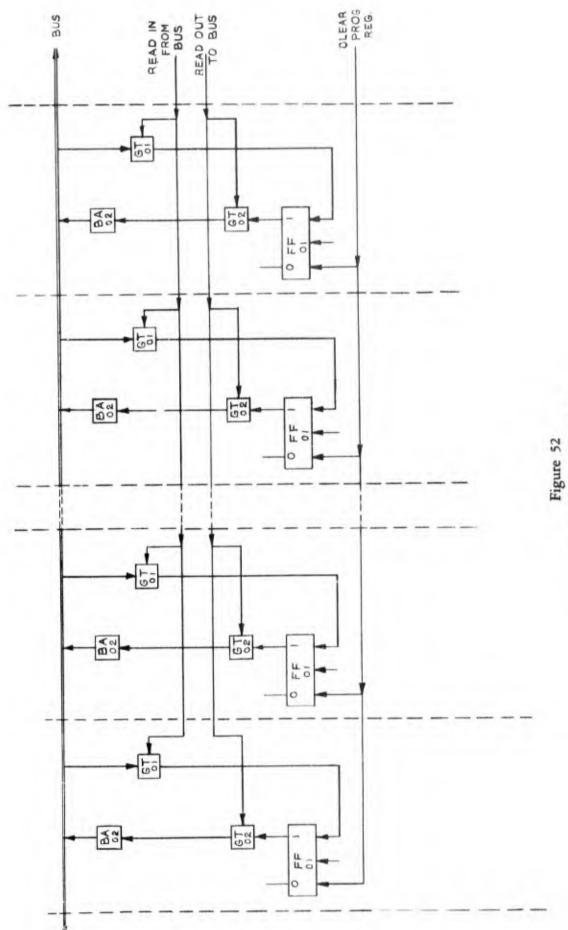
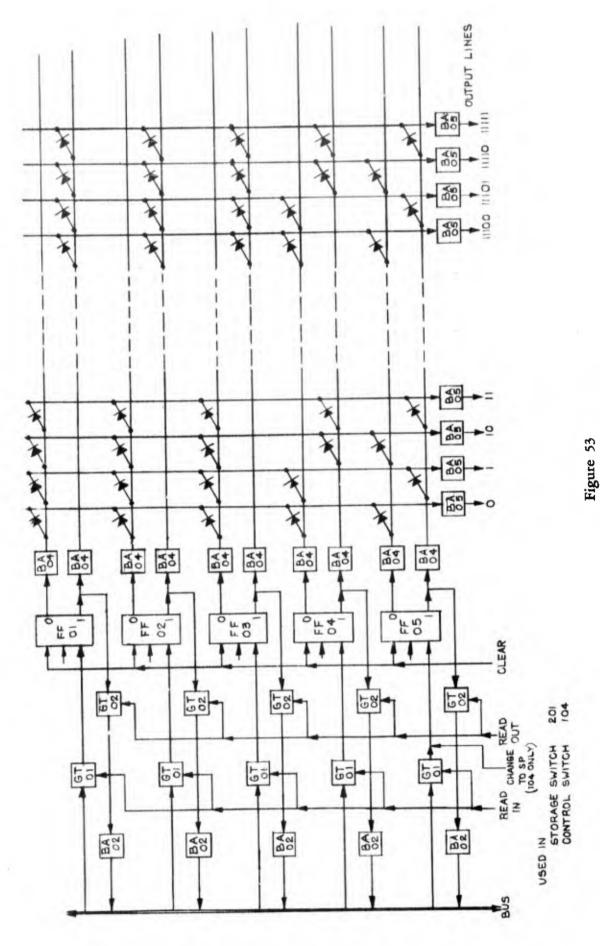


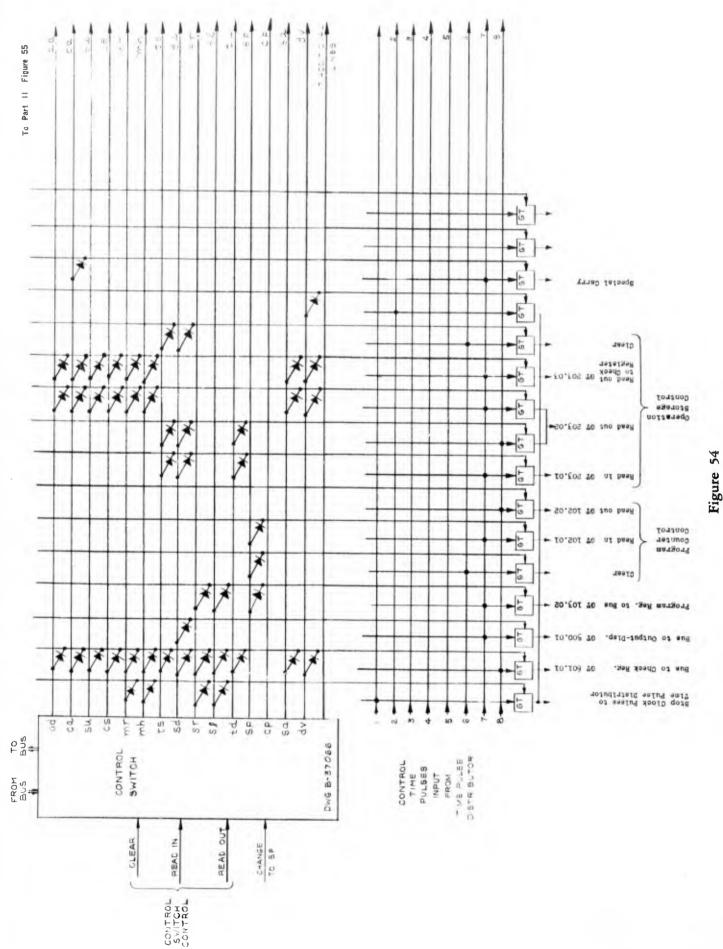
Figure 51 PROGRAM COUNTER



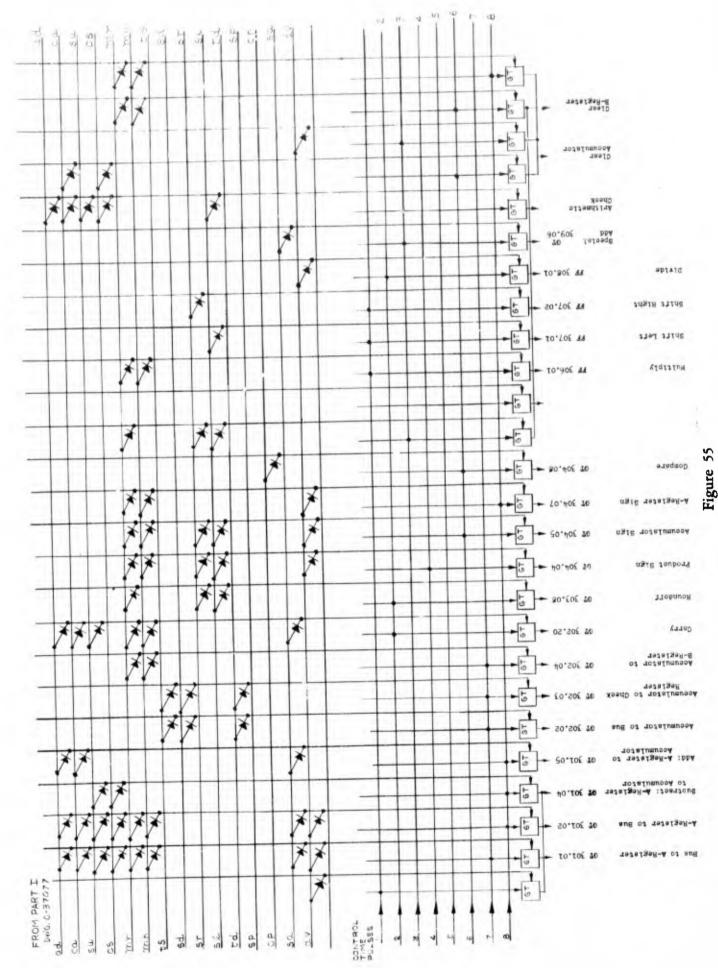
PROGRAM REGISTER



CONTROL SWITCH



OPERATION MATRIX I



OPERATION MATRIX II

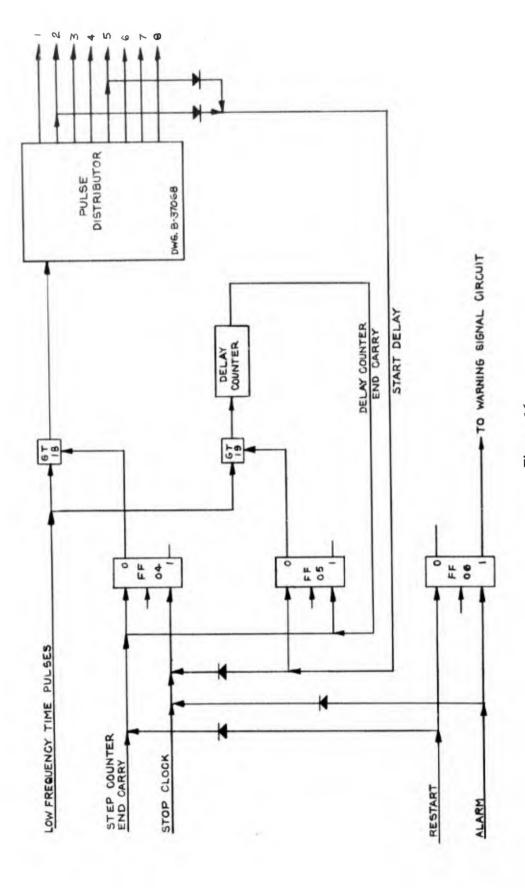
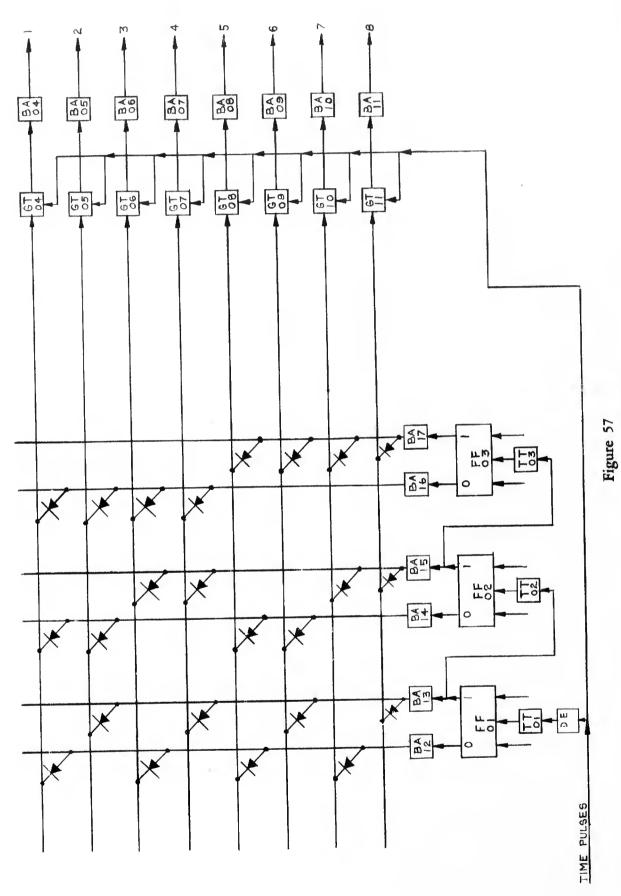
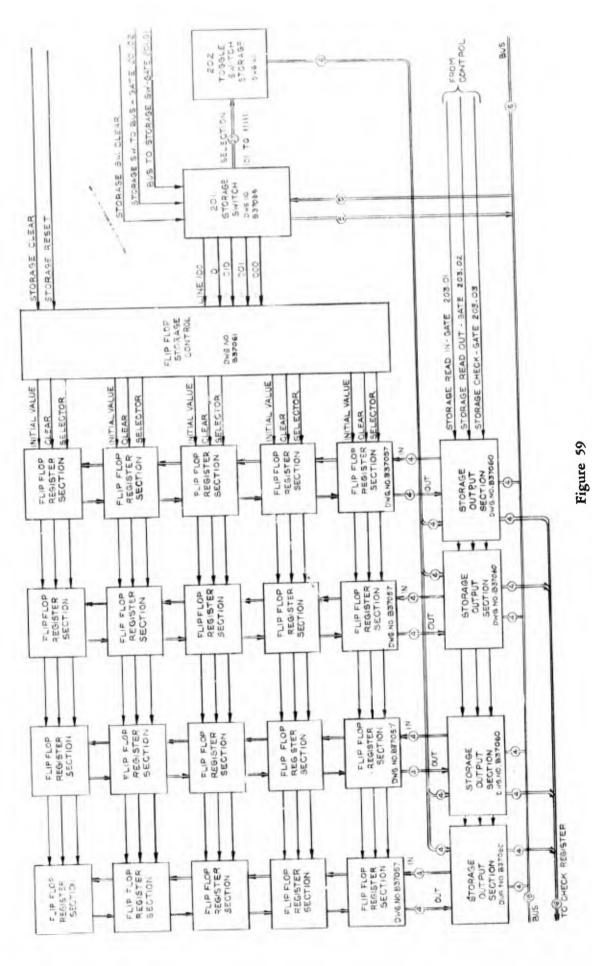


Figure 56 TIME PULSE DISTRIBUTOR CONTROL



PULSE DISTRIBUTOR

Figure 58
PROGRAM TIMING MATRIX



STORAGE CHASSIS ARRANGEMENT

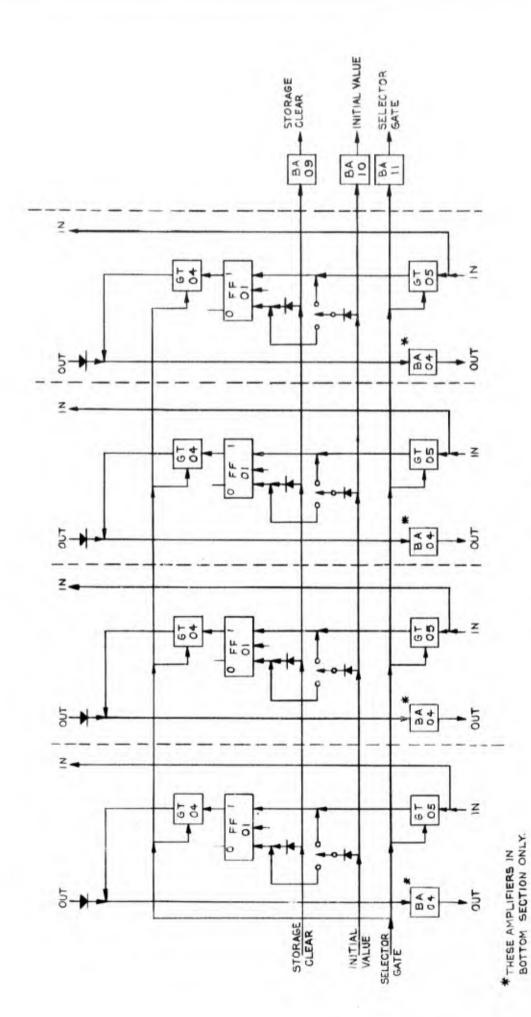


Figure 60
FLIP-FLOP STORAGE SECTION

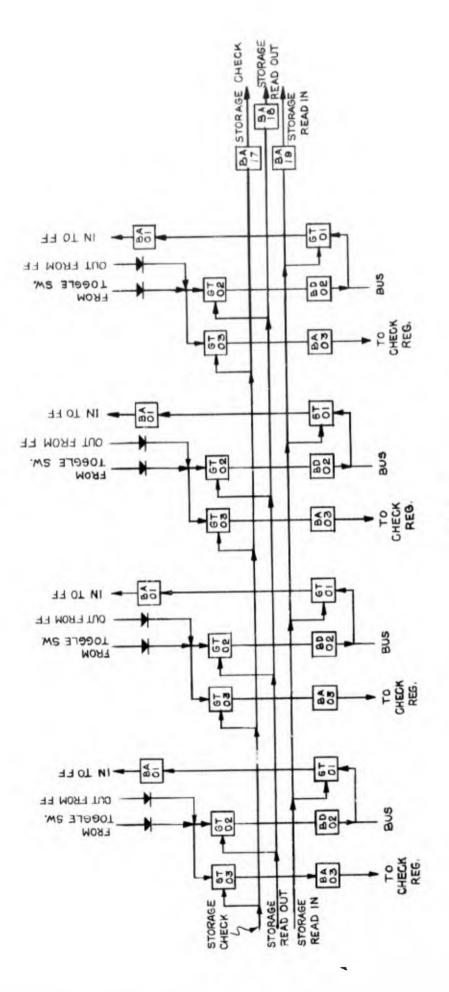
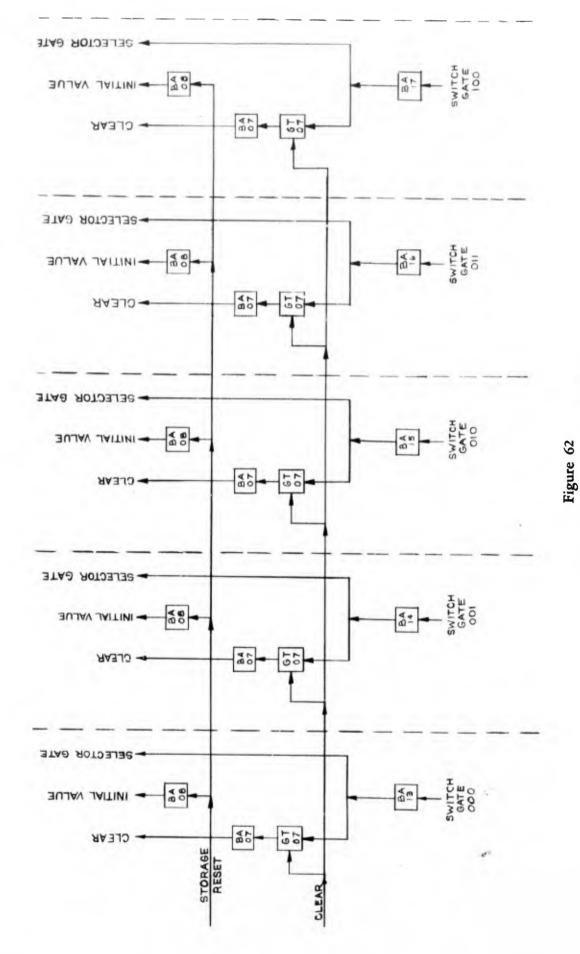
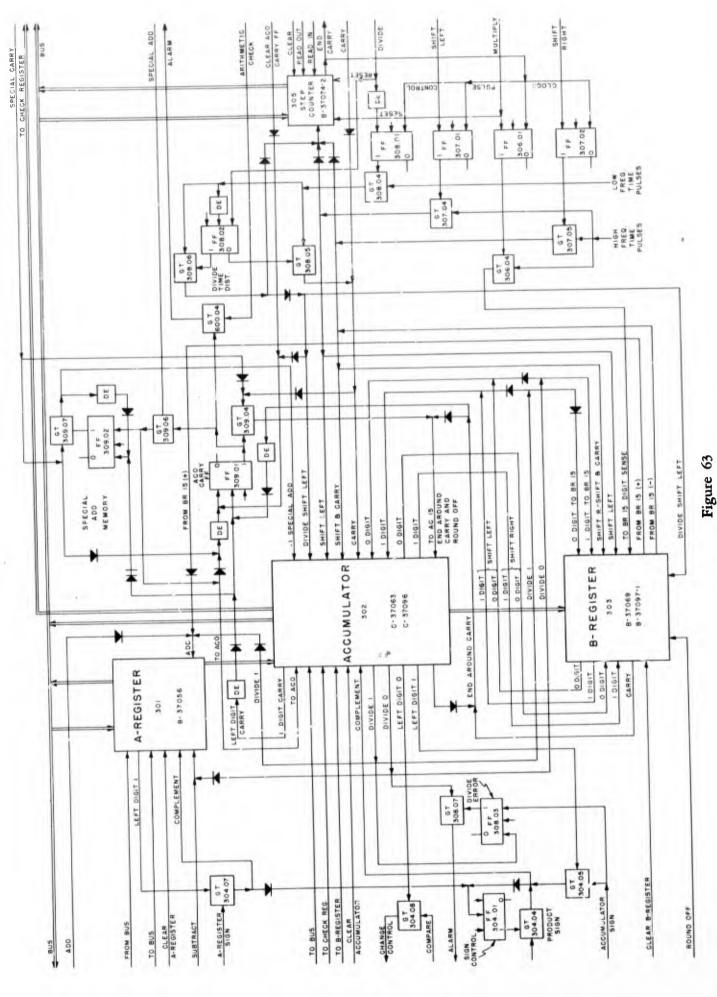


Figure 61 STORAGE OUTPUT SECTION



FLIP-FLOP STORAGE CONTROL



ARITHMETIC ELEMENT

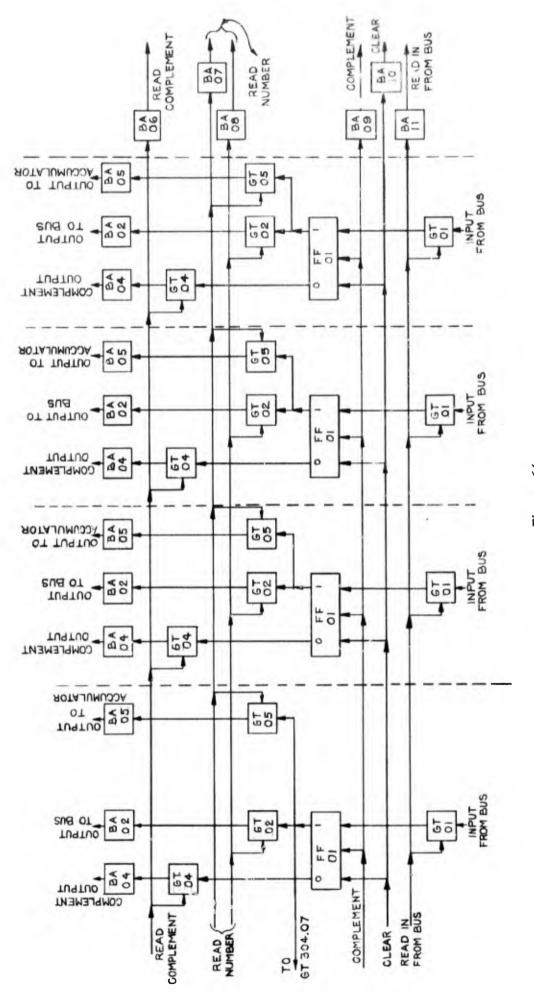


Figure 64
SECTION OF A-REGISTER

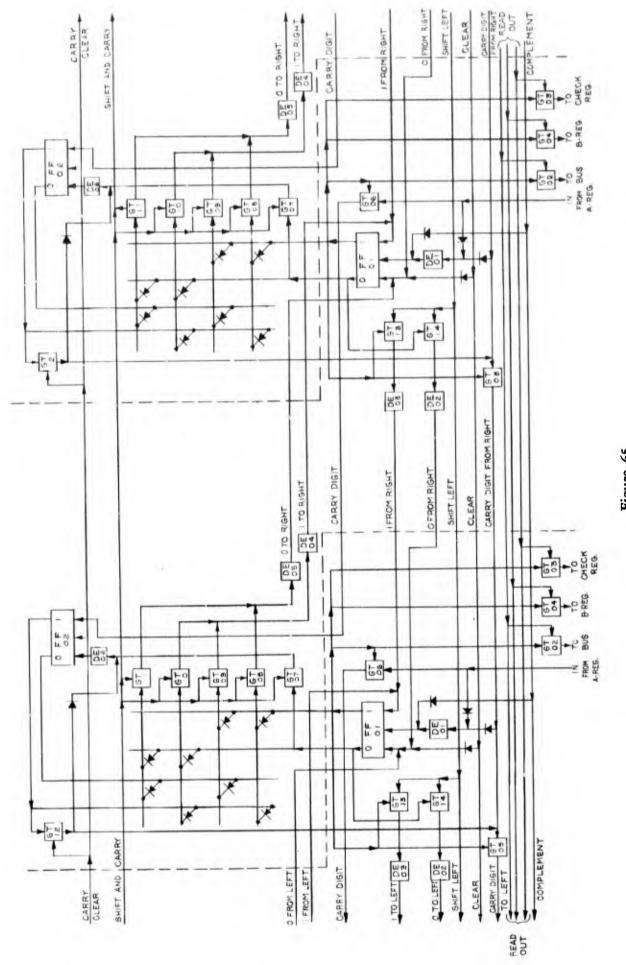
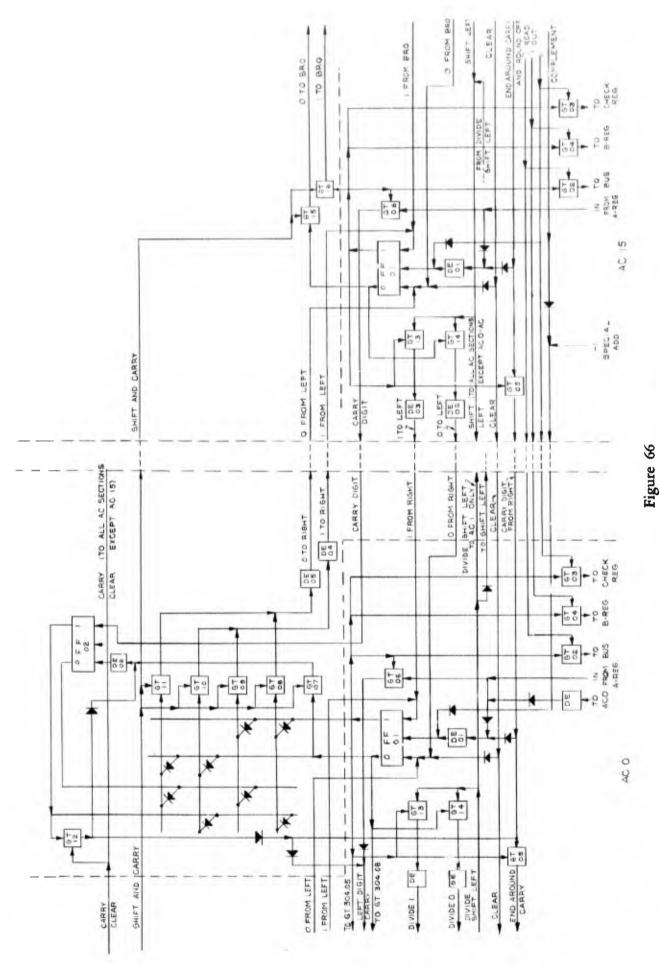
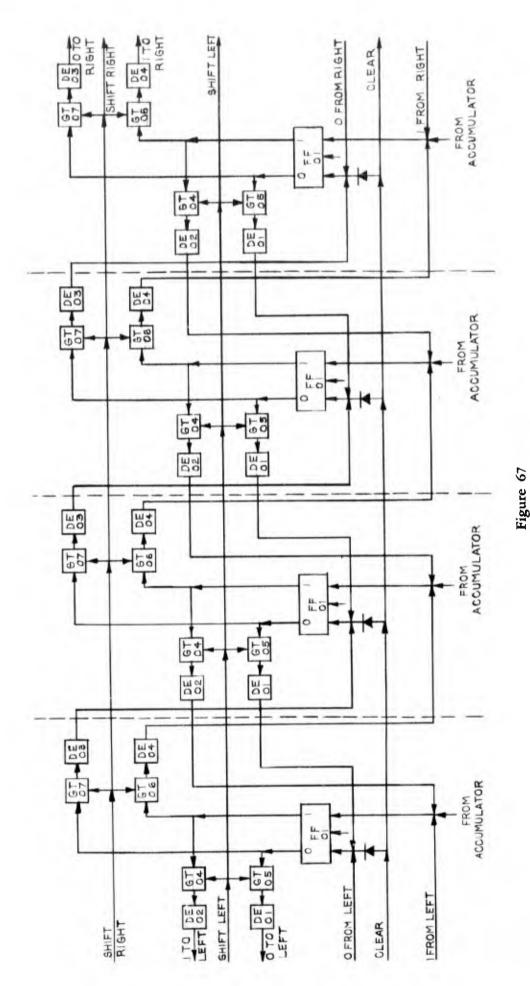


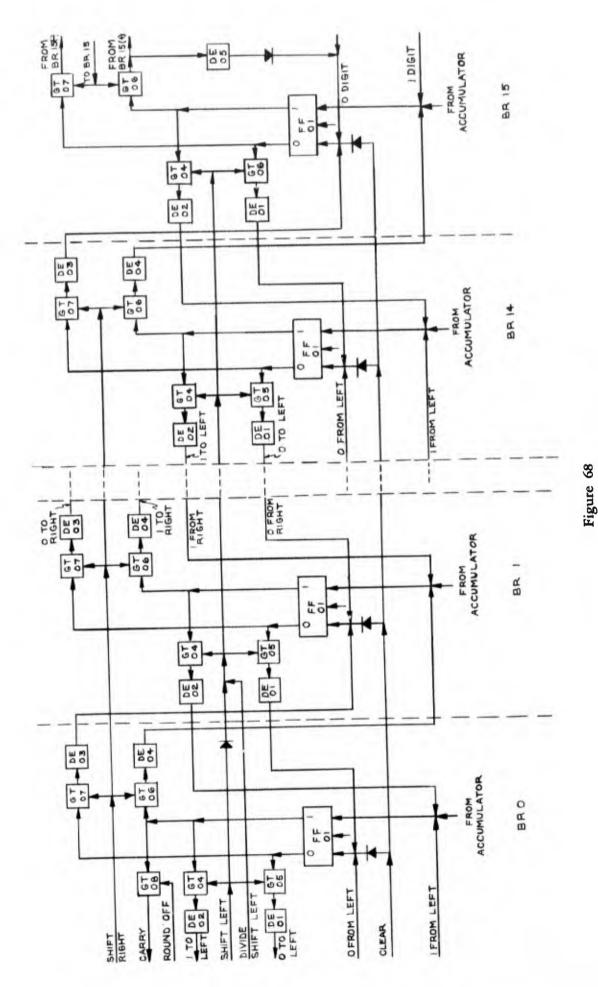
Figure 65
ACCUMULATOR SECTIONS



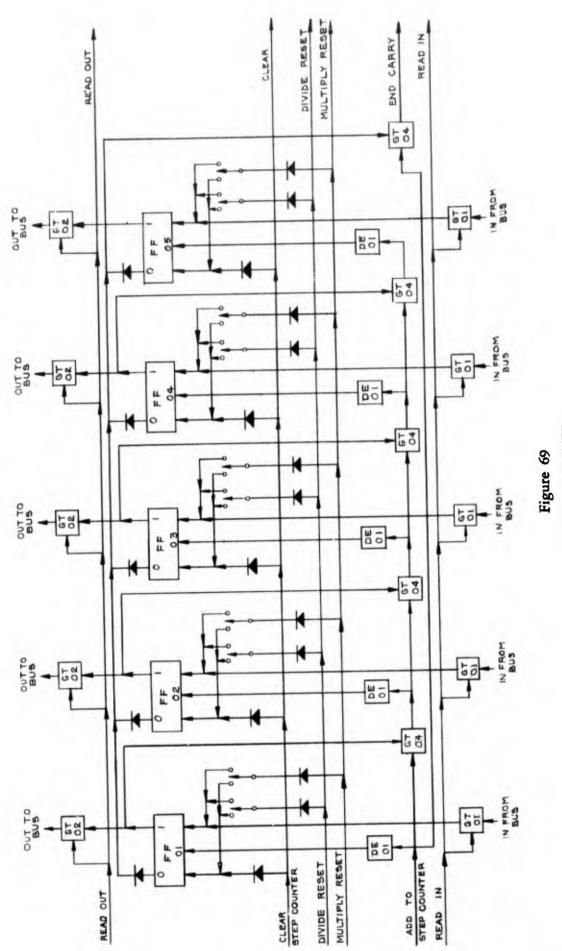
ACCUMULATOR SECTIONS AC0-AC15



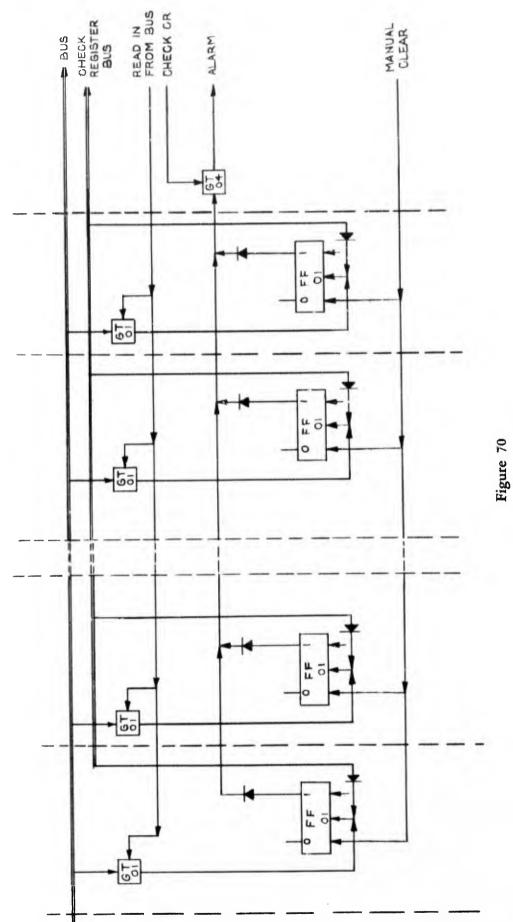
B-REGISTER SECTIONS



B-REGISTER SECTIONS BR 0, 1, 14, 15



STEP COUNTER



CHECK REGISTER

CONTROL TIME PULSES

					-	-	-			•	•	-	-				•		
-	-					-	-					-	-	-				-	
GT 102.02	GT 102.03	103.01 TO	GT 103.02	10401 TO	GT 104.02	GT 201.01	GT 201,02	GT 203.02	GT203.0\$	GT 305.01	GT 305,02	GT 601.01	1	1	!	1 1	1		1
PROGRAM COUNTER TO BUS	PROG COUNTER TO CHECK REGISTER.	BUS TO PROGRAM REGISTER	PROGRAM REGISTER TO BUS	BUS TO CONTROL SWITCH	CONTROL SWITCH TO BUS	BUS TO STORAGE SWITCH	STORAGE SWITCH TO BUS	STORAGE READOUT	STORAGE TO CHECK REGISTER	BUS TO STEP COUNTER	STEP COUNTER TO BUS	BUS TO CHECK REGISTER	START DELAY COUNTER	ADD TO PROGRAM COUNTER _	CLEAR CONTROL SWITCH	CLEAR STORAGE SWITCH	CLEAR A-REGISTER	CLEAR PROGRAM REGISTER	CLEAR STEP COUNTER

Figure 71 PROGRAM TIMING

1 2 3 4 5 6 7 8 1 2 3 4

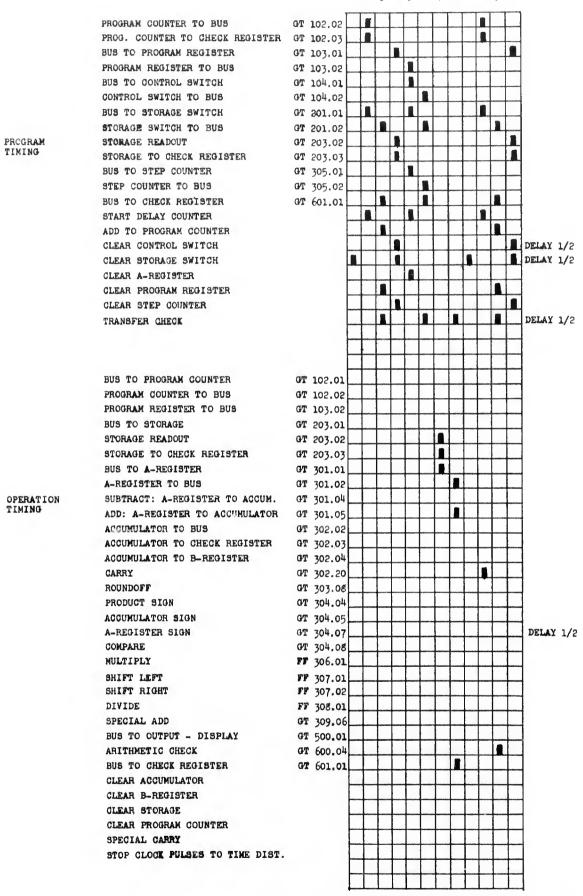


Figure 72
TIMING FOR ADD

CONTROL TIME PULSES 1 2 3 4 5 6 7 8 1 2 3 4 OT 102.02 PROGRAM COUNTER TO BUS PROG. COUNTER TO CHECK REGISTER OF 102.03 OT 103.01 BUS TO PROGRAM REGISTER GT 103.02 PROGRAM REGISTER TO BUS OT 104.01 BUS TO CONTROL SWITCH OT 104.02 CONTROL SWITCH TO BUS GT 201.01 BUS TO STORAGE SWITCH OT 201.02 STORAGE SWITCH TO BUS OT 203.02 STORAGE READOUT 1 STORAGE TO CHECK REGISTER OT 203.03 BUS TO STEP COUNTER GT 305.01 OT 305.02 STEP COUNTER TO BUS BUS TO CHECK REGISTER OT 601.01 START DELAY COUNTER ADD TO PROGRAM COUNTER DELAY 1/2 CLEAR CONTROL SWITCH DELAY 1/2 CLEAR STORAGE SWITCH CLEAR A-REGISTER CLEAR PROGRAM REGISTER CLEAR STEP COUNTER DELAY 1/2 TRANSFER CHECK BUS TO PROGRAM COUNTER OT 102.01 PROGRAM COUNTER TO BUS OT 102.02 GT 103.02 PROGRAM REGISTER TO BUS OT 203.01 BUS TO STORAGE OT 203.02 STORAGE READOUT OT 203.03 STORAGE TO CHECK REGISTER OT 301.01 BUS TO A-REGISTER OT 301.02 A-REGISTER TO BUS GT 301.04 SUBTRACT: A-REGISTER TO ACCUM. GT 301.05 ADD: A-REGISTER TO ACCUMULATOR ACCUMULATOR TO BUS OT 302.02 ACCUMULATOR TO CHECK REGISTER OT 302.03 ACCUMULATOR TO B-REGISTER OT 302.04 OT 302.20 OT 303.08 ROUNDOFF OT 304.04 PRODUCT SIGN OT 304.05 ACCUMULATOR SIGN DELAY 1/2 OT 304.07 A-REGISTER SIGN OT 304.08 COMPARE FF 306.01 MULTIPLY FF 307.01 SHIFT LIFT SHIFT RIGHT FF 307.02

Figure 73 TIMING FOR CLEAR AND ADD

FF 308.01

OT 309.06

OT 500.01 OT 600.04

OT 601.01

PROGRAM TIMING

> **OPERATION** TIMING

> > CARRY

DIVIDE

SPECIAL ADD

ARITHMETIC CHECK

BUS TO OUTPUT - DISPLAY

BUS TO CHECK REGISTER CLEAR ACCUMULATOR CLEAR B-REGISTER CLEAR STORAGE CLEAR PROGRAM COUNTER SPECIAL CARRY

STOP CLOCK PULSES TO TIME DIST

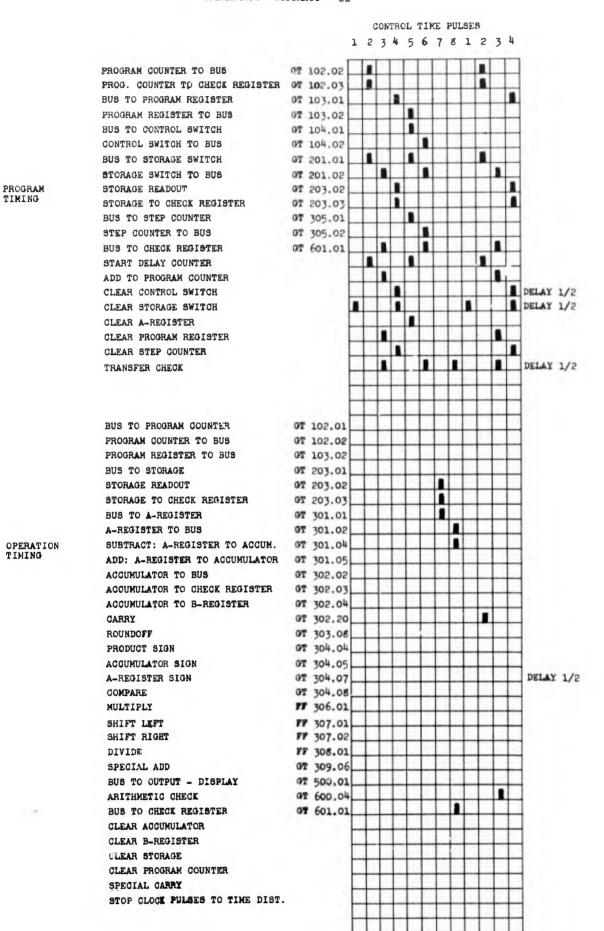


Figure 74
TIMING FOR SUBTRACT

CONTROL TIME PULSES
1 2 3 4 5 6 7 8 1 2 3 4

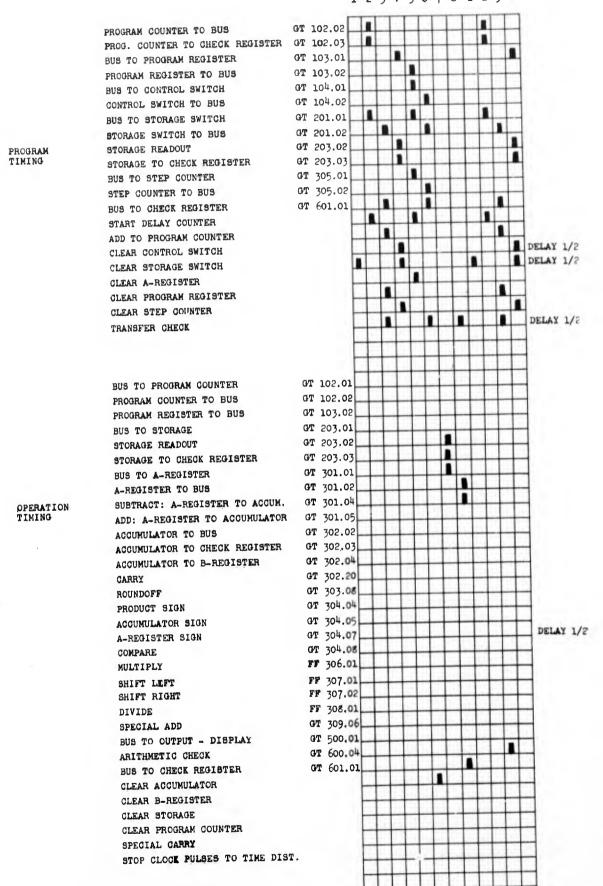


Figure 75
TIMING FOR CLEAR AND SUBTRACT

CONTROL TIME PULSES 1 2 3 4 5 6 7 8 1 2 3 4 PROGRAM COUNTER TO BUS OT 102.02 PROG. COUNTER TO CHECK REGISTER OT 102.03 BUS TO PROGRAM REGISTER OT 103.01 PROGRAM REGISTER TO BUS OT 103.02 BUS TO CONTROL SWITCH GT 104.01 OT 104.02 CONTROL SWITCH TO BUS BUS TO STORAGE SWITCH GT 201.01 STORAGE SWITCH TO BUS OT 201.02 PROGRAM STORAGE READOUT OT 203.02 TIMING STORAGE TO CHECK REGISTER OT 203.03 BUS TO STEP COUNTER OT 305.01 STEP COUNTER TO BUS OT 305.02 BUS TO CHECK REGISTER OT 601.01 START DELAY COUNTER ADD TO PROGRAM COUNTER CLEAR CONTROL SWITCH DELAY 1/2 CLEAR STORAGE SWITCH DELAY 1/2 CLEAR A-REGISTER CLEAR PROGRAM REGISTER CLEAR STEP COUNTER DELAY 1/2 TRANSFER CHECK BUS TO PROGRAM COUNTER OT 102.01 PROGRAM COUNTER TO BUS GT 102.02 PROGRAM REGISTER TO BUS OT 103.02 BUS TO STORAGE OT 203.01 STORAGE READOUT OT 203.02 STORAGE TO CHECK REGISTER GT 203.03 BUS TO A-REGISTER OT 301.01 A-REGISTER TO BUS GT 301.02 OPERATION TIMING SUBTRACT: A-REGISTER TO ACCUM. GT 301.04 ADD: A-REGISTER TO ACCUMULATOR GT 301.05 ACCUMULATOR TO BUS OT 302.02 OT 302.03 ACCUMULATOR TO CHECK REGISTER ACCUMULATOR TO B-REGISTER OT 302.04 CARRY OT 302.20 ROUNDOFF OT 303.08 OT 304.04 PRODUCT SIGN ACCUMULATOR SIGN GT 304.05 A-REGISTER SIGN OT 304.07 DELAY 1/2 COMPARE OT 304.08 MULTIPLY FF 306.01 SHIFT LEFT FF 307.01 SHIFT RIGHT FF 307.02 DIVIDE FF 308.01 SPECIAL ADD OT 309.06 BUS TO OUTPUT - DISPLAY GT 500.01 ARITHMETIC CHECK GT 600.04 BUS TO CHECK REGISTER OT 601.01 CLEAR ACCUMULATOR CLEAR B-REGISTER CLEAR STORAGE CLEAR PROGRAM COUNTER SPECIAL CARRY STOP CLOCK PULSES TO TIME DIST.

Figure 76
TIMING FOR MULTIPLY AND ROUNDOFF

1 2 3 4 5 6 7 8 1 2 3 4

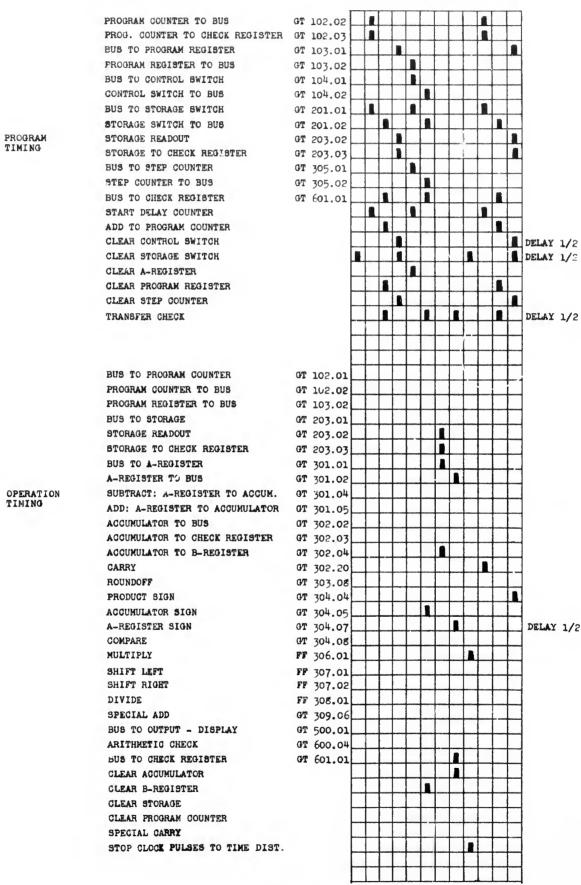
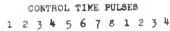


Figure 77

TIMING FOR MULTIPLY AND HOLD FULL PRODUCT



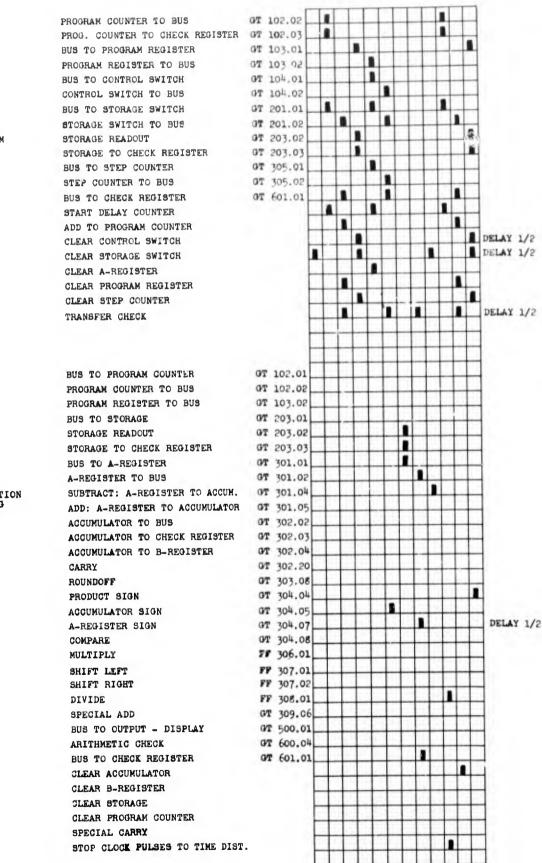


Figure 78
TIMING FOR DIVIDE

PROGRAM

OPERATION TIMING

CONTROL TIME PULSES
1 2 3 4 5 6 7 8 1 2 3 4

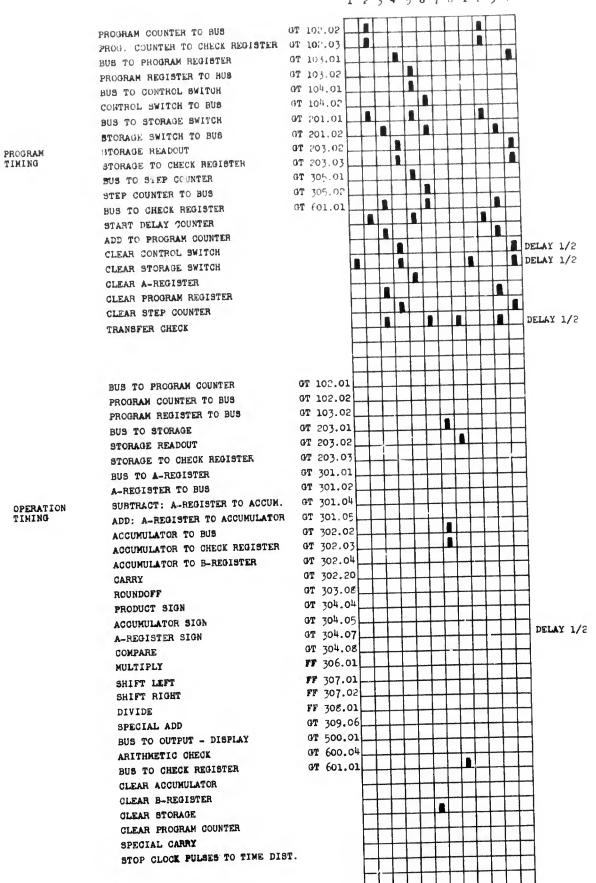


Figure 79
TIMING FOR TRANSFER TO STORAGE

PROGRAM COUNTER TO BUS

BUS TO PROGRAM REGISTER

PROGRAM REGISTER TO BUS

BUS TO CONTROL SWITCH

CONTROL SWITCH TO BUS

BUS TO STORAGE SWITCH STORAGE SWITCH TO BUS

BUS TO STEP COUNTER

STORAGE TO CHECK REGISTER

STORAGE READOUT

CONTROL TIME PULSES 1 2 3 4 5 6 7 8 1 2 3 4 QT 102.02 PROG. COUNTER TO CHECK REGISTER GT 102.03 GT 103.01 OT 103.02 OT 104.01 GT 104.02 OT 201.01 OT 201.02 GT 203.02 or 203.03 GT 305.01 OT 305.02 OT 601.01 DELAY 1/2 DELAY 1/2 DELAY 1/2 OT 102.01 OT 102.02 OT 103.02 OT 203.01 OT 203.02 GT 203.03 OT 301.01 OT 301.02 GT 301.04 GT 301.05 OT 302.02 OT 302.03 OT 302.04 OF 302.20 OT 303.08 OT 304.04 or 304.05 DELAY 1/2 GT 304.07

OPERATION TIMING

PROGRAM

TIMING

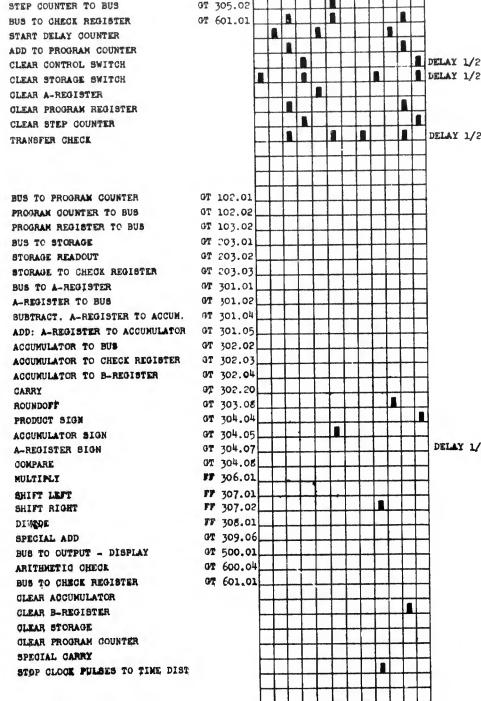


Figure 80 TIMING FOR SHIFT RIGHT

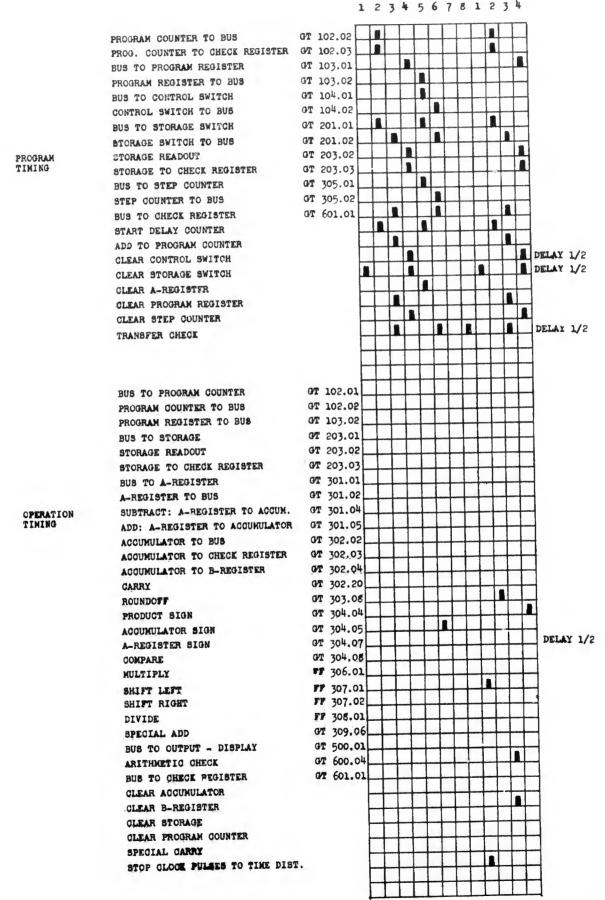


Figure 81
TIMING FOR SHIFT LEFT

1 2 3 4 5 6 7 8 1 2 3 4 OT 102.02 PROGRAM COUNTER TO BUS PROG. COUNTER TO CHECK REGISTER GT 102.03 BUS TO PROGRAM REGISTER GT 103.01 PROGRAM REGISTER TO BUS GT 103.02 BUS TO CONTROL SWITCH GT 104.01 GT 104.02 CONTROL SWITCH TO BUS BUS TO STORAGE SWITCH GT 201.01 STORAGE SWITCH TO BUS OT 201.02 PROGRAM STORAGE READOUT OT 203.02 TIMING STORAGE TO CHECK REGISTER GT 203.03 GT 305.01 BUS TO STEP COUNTER GT 305.02 STEP COUNTER TO BUS GT 601.01 BUS TO CHECK REGISTER START DELAY COUNTER ADD TO PROGRAM COUNTER DELAY 1/2 CLEAR CONTROL SWITCH DELAY 1/2 CLEAR STORAGE SWITCH CLEAR A-REGISTER 1 CLEAR PROGRAM REGISTER CLEAR STEP COUNTER DELAY 1/2 TRANSFER CHECK BUS TO PROGRAM COUNTER OT 102.01 PROGRAM COUNTER TO BUS OT 102.02 OT 103.02 PROGRAM REGISTER TO BUS BUS TO STORAGE OT 203.01 GT 203.02 STORAGE READOUT GT 203.03 STORAGE TO CHECK REGISTER OT 301.01 BUS TO A-REGISTER GT 301.02 A-REGISTER TO BUS GT 301.04 SUBTRACT: A-REGISTER TO ACCUM. OPERATION TIMING ADD: A-REGISTER TO ACCUMULATOR GT 301.05 GT 302.02 ACCUMULATOR TO BUS GT 302.03 ACCUMULATOR TO CHECK REGISTER OT 302.04 ACCUMULATOR TO B-REGISTER GT 302.20 CARRY GT 303.08 ROUNDOFF GT 304.04 PRODUCT SIGN GT 304.05 ACCUMULATOR SIGN DELAY 1/2 GT 304.07 A-REGISTER SIGN GT 304.08 COMPARE MULTIPLY FF 306.01 SHIFT LEFT FF 307.01 SHIFT RIGHT FF 307.02 FF 308.01 or 309.06 SPECIAL ADD BUS TO OUTPUT - DISPLAY GT 500.01 OT 600.04 ARITHMETIC CHECK OT 601.01 BUS TO CHECK REGISTER CLEAR ACCUMULATOR CLEAR B-REGISTER CLEAR STORAGE CLEAR PROGRAM COUNTER SPECIAL CARRY STOP CLOCK PULSES TO TIME DIST.

Figure 82
TIMING FOR SUBPROGRAM

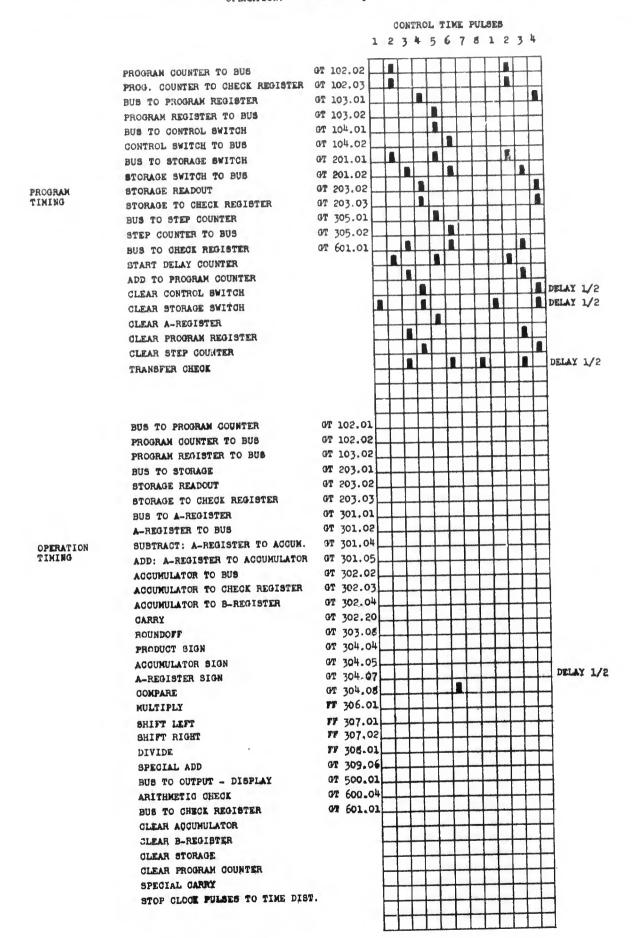


Figure 83
TIMING FOR CONDITIONAL PROGRAM

CONTROL TIME PULSES 1 2 3 4 5 6 7 8 1 2 3 4 OT 102.02 PROGRAM COUNTER TO BUS PROG. COUNTER TO CHECK REGISTER OF 102.03 BUS TO PROGRAM REGISTER OT 103.01 PROGRAM REGISTER TO BUS OF 103.02 OT 104.01 BUS TO CONTROL SWITCH CONTROL SWITCH TO BUS OT 104.02 BUS TO STORAGE SWITCH OT 201.01 STORAGE SWITCH TO BUS 07 201.02 STORAGE READOUT OT 203.02 STORAGE TO CHECK REGISTER GT 203.03 OT 305.01 BUS TO STEP COUNTER OT 305.02 STEP COUNTER TO BUS OT 601.01 BUS TO CHECK REGISTER START DELAY COUNTER ADD TO PROGRAM COUNTER DELAY 1/2 CLEAR CONTROL SWITCH DELAY 1/2 CLEAR STORAGE SWITCH CLEAR A-REGISTER CLEAR PROGRAM REGISTER CLEAR STEP COUNTER DELAY 1/2 TRANSFER CHECK BUS TO PROGRAM COUNTER OT 102.01 PROGRAM COUNTER TO BUS OT 102.02 PROGRAM REGISTER TO BUS OT 103.02 OT 203.01 BUS TO STORAGE STORAGE READOUT OT 203.02 STORAGE TO CHECK REGISTER OT 203.03 OT 301.01 BUS TO A-REGISTER A-REGISTER TO BUS OT 301.02 SUBTRACT: A-REGISTER TO ACCUM. OT 301.04 ADD: A-REGISTER TO ACCUMULATOR OT 301.05 ACCUMULATOR TO BUS OT 302.02 ACCUMULATOR TO CHECK REGISTER GT 302.03 ACCUMULATOR TO B-REGISTER OT 302.04 CARRY OT 302.20 ROUNDOFF OT 303.08 PRODUCT SIGN OT 304.04 ACCUMULATOR SIGN GT 304.05 DELAY 1/2 OT 304.07 A-REGISTER SIGN COMPARE OT 304.08 MULTIPLY FF 306,01 FF 307.01 SHIFT LEFT FF 307.02 SHIFT RIGHT FF 308.01 DIVIDE OT 309.06 SPECIAL ADD BUB TO OUTPUT - DISPLAY OT 500.01 ARITHMETIC CHECK 07 600.04 BUS TO CHECK REGISTER 07 601.01 CLEAR ACCUMULATOR CLEAR B-REGISTER CLEAR STORAGE CLEAP PROGRAM COUNTER

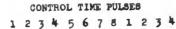
Figure 84
TIMING FOR TRANSFER DIGITS

SPECIAL CARRY

STOP CLOCK PULSES TO TIME DIST.

PROGRAM TIMING

OPERATION TINING



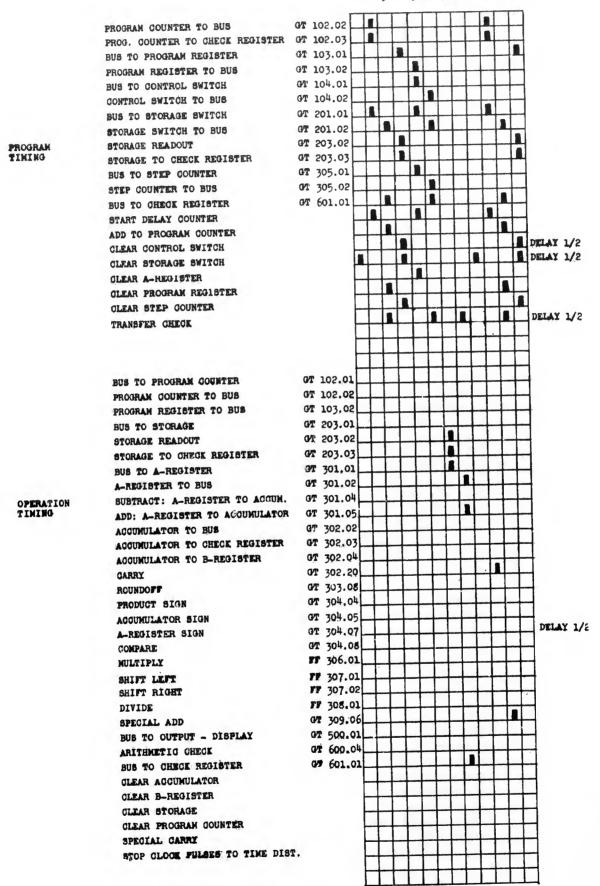


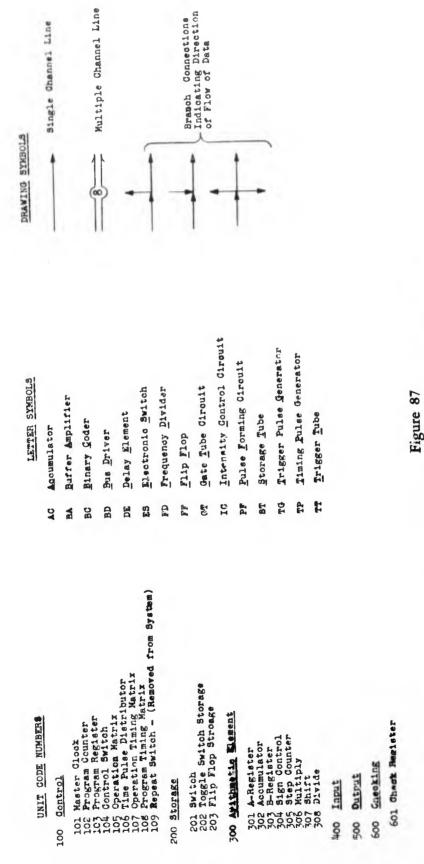
Figure 85
TIMING FOR SPECIAL ADD

1 2 3 4 5 6 7 8 1 2 3 4 OT 102.02 PROGRAM COUNTER TO BUS PROG. COUNTER TO CHECK REGISTER GT 102.03 BUS TO PROGRAM REGISTER GT 103.01 PROGRAM REGISTER TO BUS GT 103.02 GT 104.01 BUS TO CONTROL BWITCH GT 104.02 CONTROL SWITCH TO BUS GT 201.01 BUS TO STORAGE SWITCH GT 201.02 FIORAGE SWITCH TO BUS GT 203.02 STORAGE READOUT STORAGE TO CHECK REGISTER GT 203.03 BUS TO STEP COUNTER GT 305.01 STEP COUNTER TO BUS GT 305.02 GT 601.01 BUS TO CHECK REGISTER START DELAY COUNTER ADD TO PROGRAM COUNTER DELAY 1/2 CLEAR CONTROL SWITCH DELAY 1/2 CLEAR STORAGE SWITCH CLEAR A-REGISTER . CLEAR PROGRAM REGISTER CLEAR STEP COUNTER DELAY 1/2 TRANSFER CHECK BUS TO PROGRAM COUNTER GT 102.01 GT 102.02 PROGRAM COUNTER TO BUS GT 103.02 PROGRAM REGISTER TO BUS GT 203.01 BUS TO STORAGE GT 203.02 STORAGE READOUT GT 203.03 STORAGE TO CHECK REGISTER OT 301.01 BUS TO A-REGISTER A-REGISTER TO BUS GT 301.02 SUBTRACT: A-REGISTER TO ACCUM. GT 301.04 ADD: A-REGISTER TO ACCUMULATOR OT 301.05 GT 302.02 ACCUMULATOR TO BUS OT 302.03 ACCUMULATOR TO CHECK REGISTER OT 302.04 ACCUMULATOR TO B-REGISTER OT 302.20 CARRY OF 303.08 ROUNDOFF GT 304.04 PRODUCT SIGN GT 304.05 ACCUMULATOR SIGN DELAY 1/2 A-REGISTER SIGN OT 304.07 OT 304.08 COMPARE FF 306.01 MULTIPLY SHIFT LEFT FF 307.01 FF 307.02 SHIFT RIGHT FF 308.01 DIVIDE OT 309.06 SPECIAL ADD BUS TO OUTPUT - DISPLAY GT 500.01 ARITHMETIC CHECK GT 600.04 BUS TO CHECK REGISTER OT 601.01 CLEAR ACCUMULATOR CLEAR B-REGISTER CLEAR STORAGE CLEAR PROGRAM COUNTER SPECIAL CARRY STOP CLOCK PULSES TO TIME DIST.

Figure 86
TIMING FOR STORE AND DISPLAY

PROGRAM TIMING

> OPERATION TIMING



PARALLEL DIGIT COMPUTER CODES